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A Study of the Dosage-Mortality Curve

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The form of the dosage-mortality curve has engaged the attention of many students. Strand (1930) concluded that its form was sigmoid. O'Kane *et al.* (1930) and Gaddum (1933) have called attention to the possibilities of the logarithmic and probability transformation, and Bliss (1935a, 1938) has developed this interpretation.

When percentages of mortality are plotted against units of concentration, the distribution of the points, as shown in figure 1, indicates a curve. When these percentages are transformed to probability units, or "probits" (Bliss, 1935a, 1938) and plotted against concentrations expressed as logarithms, the curve tends to be a straight line (Fig. 2). This approximate linearity makes possible the simplification of statistical procedure. When probits that have been calculated from the equation of the straight line are converted to percentages, and these values are plotted against the corresponding concentrations, expressed as the antilogarithms, or original units, a smooth curve, somewhat **S**-shaped with the upper bend more pronounced, results.

Several considerations have led the writers to further study. The basic assumptions in the log-probit transformation are that increase in concentration takes effect logarithmically and that susceptibility is normally distributed among individuals. The curve plotted directly has been described as asymmetrically sigmoid. The transformation of concentrations to logarithms is expected to make the curve symmetrical, and the transformation of percentages of mortality to probability units, or probits, to make it linear. The strictest interpretation of normality of susceptibility will lead to the conclusion that 100 per cent mortality will not be attained by any finite concentration, and that zero mortality can occur only at zero concentration (if the number taken is large). The idea of the impossibility of 100 per cent mortality is viewed with skepticism by some toxicologists (Shepard 1939) and an apparent threshold toxic concentration different from zero is commonly observed. It is noted that since many available sets of data are based on only small numbers and are irregular in distribution, a number of curves might fit.

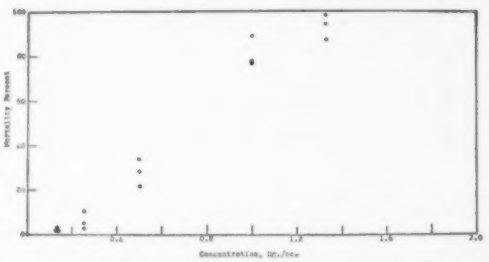

FIG. 1.—Daily mean percentages of mortality of houseflies plotted against concentrations of pyrethrum extract.

When efforts have been made to fit curves to untransformed data, the lower bend in the asymmetric curve has been found to be so poorly defined that in many cases its existence might be ignored with little risk.

In many sets of published and unpublished data transformed as mentioned above there seems to be a persistent tendency for the graph to curve upward, a fact which is often recognized by fitting two separate lines to different parts of the range. This persistent deviation from linearity seems more marked when the numbers used are large and the points are precisely determined. Therefore the extrapolation sometimes used seems of doubtful wisdom.

Experiments were conducted by the writers to test several of the questions just discussed. The problems of the extremes of

the curve, of the reality of the lower bend of the curve in untransformed data, and of the linearity of the curve in transformed data were included. Adult houseflies were sprayed with pyrethrum extract in acetone by the turntable method (Campbell and Sullivan, 1938). Concentrations of pyrethrins of 0.031, 0.125, 0.25, 0.5, 1.0, 1.33, 2.0, and 5.0 milligrams per cubic centimeter were used. Three tests were run at each concentration on each of three days, and 100 to 160 flies, averaging about 135, were used in each test. An untreated check and an acetone check were used with each set. Mortality in these checks averaged less than 1 per cent and was not perceptibly greater in the lowest pyrethrum concentration (0.031). The 6 concentrations from 0.125 to 2.0 milligrams, inclusive, gave mortalities averaging about 3, 7, 29, 81, 93, and 98 per cent respectively. The concentration of 5.0 milligrams gave consistently a mortality of 100 per cent in all 9 tests with over 1200 flies.

Table 1.—Analysis of variance of equivalent angles of mortality observed in the flies used as checks and in those receiving the lowest concentration of pyrethrum.

Source of Variation	Degrees of Freedom	Mean Square
Between treatments	2	12.92
Between days	2	18.16
Between orders of treatment[1]	2	6.11
Interactions		
Treatment×order	4	3.79
Treatment×day	4	9.22
Order×day	4	2.12
Treatment×order×day	8	4.74

[1] Comparison of orders of treatment involves a comparison of the first, second, and third sets of tests on each day.

First the mortalities for the lowest concentration of pyrethrum were compared with the natural mortalities of the untreated check and the acetone check. These percentages, ranging in individual cases from zero to 2.29 but in most cases with some mortality, were transformed to equivalent angles. The analysis is summarized in table 1. If the last three interactions involving days are lumped as error, none of the variances show as significant although the variance for days is almost significant. Thus by a very critical analysis the lowest concentration could not be found to be different from no treatment in the mortality observed.

When a similar analysis that included the two lowest pyrethrum concentrations was conducted, a significant difference between treatments resulted, indicating that the effect of the second concentration (0.125 mg. per cc.) differs significantly from that from no treatment. The difference between days again approached significance.

Next, the question of mortality at the upper extremes was studied. As stated, over 1200 insects were used in 9 tests at a concentration of 5.0 milligrams per cubic centimeter with no survival. However, in a tentative fitting of a straight line for the 6 concentrations above 0.031 and below 5.0, with concentrations expressed as logarithms and percentages of mortality as probits, an extrapolation gave an estimate of only 2 insects surviving for each 10,000. Hence the numbers used here did not provide a critical test of the accuracy of extrapolation. Such a test would not be afforded by even 5000 or 10,000 insects, because when only 1 or 2 are expected to survive on the average, random sampling can easily give zero in a particular case. Hence zero survival with 10,000 insects would not disprove a probability of average survival of 2. If 20,000 or more insects had been used, zero survival would have more weight, since it is unsuual to get zero by random sampling from a population averaging 4 or more per sample.

General trends in the material then received attention. Concentrations from 0.25 to 1.33 milligrams per cubic centimeter, inclusive, were carefully studied. As had already been noted in analyses of material near the threshold, no difference whatever between orders of treatment could be observed. A pronounced difference, of course, was shown between concentrations. There was a significant difference between days, although it was much less marked. The interaction of day and concentration was not at all significant; this indicates that the minor difference between days was consistent. In general, trials on the same day and with the same concentration usually varied no more than would be expected from the theoretical random sampling variance of the binomial. Hence the results within each day may be viewed as homogeneous.

Percentages for days within a concentration, however, usually varied more than would be expected from this criterion.

The minor question of the lower bend of the curve was next studied. Percentages of mortality were adjusted by Abbott's formula to allow for the slight natural mortality shown by the checks and the lowest pyrethrum concentration. While any or all of these might have been used with little difference in results, the acetone check was used as most appropriate. The average for each day was used in making this slight adjustment in individual trials within a day.

The lowest pyrethrum concentration, which gave substantially zero mortality, seemed unsuited for use, since it might have been somewhat below the exact threshold. Only three concentrations remained for testing the lower bend, namely, 0.125, 0.25, and 0.5 milligram per cubic centimeter. Above 0.5 milligram the curve was inclined to become convex upward. Each day was treated separately. Analysis of variance was used on the three classes of three tests each as shown in table 2. An analysis of the three combined days, in which daily averages were used, was also carried out, since consistency of daily differences made these averages seem stable.

Table 2.—Analysis of variance of percentages of fly mortality obtained from the three concentrations of pyrethrum spray—0.125, 0.250, and 0.500 milligram per cubic centimeter—to test the lower part of the curve.

Source of Variation	Degrees of Freedom	Mean Square			
		Day A	Day B	Day C	Combined Days
Between classes	2	849.9	620.0	383.3	597.6
Linear regression	1	1,680.8	1,187.7	700.0	1,195.3
Deviation from regression	1	18.9	52.3†	67.0*	43.2
Within classes	6	10.2	1.5	8.4	19.8

* Significant.
† Highly significant.

It can be readily seen from table 2 that this lower bend does not differ markedly from a straight line, even in this material selected to give any curvature the best opportunity to show.

The question of the linearity of the curve plotted from the transformed data was then considered. The concentrations 0.125, 0.25, 0.5 , 1.0, 1.33, and 2.0 milligrams per cubic centimeter were used. Concentrations were expressed as logarithms and mortality percentages (with the slight adjustment mentioned) as probits.

The lowest concentration, which gave mortality not different from the check, was not used, nor was the highest one, which consistently gave 100 per cent

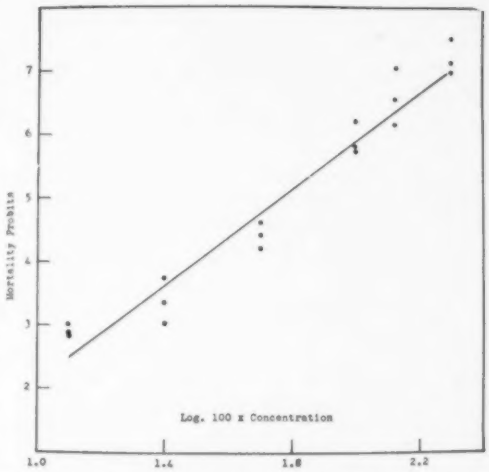

FIG. 2.—Data of figure 1 plotted as logarithms of concentration and probits of mortality, with regression line of table 3, footnote 4, fitted to daily means.

mortality. Probits might have been derived for these points, as suggested by Bliss (1935a) on the assumption that normality holds and that complete mortality cannot be achieved, and using the method of maximum likelihood. The desire to test the basic assumptions before using this procedure, however, made omission of the 100 per cent cases seem the best course. For the same reason, two instances of 100 per cent mortality in the next higher concentration on the second day and two on the third day were omitted. If included, they would have further emphasized curvilinearity. On the first day there thus remained six concentrations with three determinations at each; on the second and third days, five concentrations with three determinations at each and the sixth concentration with only one. Weights (Bliss 1935a) were not used; their use depends partly on the theory of normality and seemed unlikely to change results. Adjustment (Bliss 1938) was not used, because it is tied up with the assumptions being tested.

Curves were fitted separately for each

of the three days, as the differences between days were generally so large that a set of tests involving more than one day could not be regarded as homogeneous. A curve was also fitted to material of all three days, means of probits for each day being used for the separate determinations. This curve gives a better representation of general conditions than the curve for any one day. It is subject to a larger error in the day-to-day variation, however, and is less exact in the present study than the curves for single days. This last curve is shown in figure 2.

deviations are larger than could be expected from the general variability. Next to be studied is whether these deviations are haphazard or whether they consistently indicate a curve. Plotting indicates a gentle curve of gradually increasing steepness (Fig. 2).

A simple parabola was fitted to the data for each day. The sums of squares of deviations from this curve were compared with those from linear regression, and a notable reduction was found in each case, as summed up in table 4.

The reduction in sum of squares ob-

Table 3.—Analysis of variance of linear regression in the log.-probit curve of concentration-mortality and deviations therefrom.

Variance of Probits	Mean Square			
	Day A[1]	Day B[2]	Day C[3]	Combined Days[4]
Between concentrations	7.589 (5)[5]	7.189 (5)	9.344 (5)	9.235 (5)
Within concentrations	.064 (10)	.033 (10)	.084 (12)	.090 (12)
Between concentrations, linear regression	35.981 (1)	34.869 (1)	44.655 (1)	44.848 (1)
Between concentrations, deviations from linear regression	.491† (4)	.269† (4)	.516† (4)	.332* (4)

[1] Equation: $Y=-1.39+3.76X$.
[2] Equation: $Y=-1.56+3.71X$.
[3] Equation: $Y=-1.73+3.75X$.
[4] Equation: $Y=-1.60+3.76X$.
[5] The number of degrees of freedom for each variance is stated after it in parentheses.
* Significant.
† Highly significant.

The four curves just referred to were expressed in the form $Y=a+bX$ where X is the logarithm of 100×concentration, Y is the probit of percentage mortality, b is the regression coefficient, and a is derived as (mean Y) $-b$ (mean X). Analysis of variance to determine significance of linear regression was carried out as outlined by Snedecor (1940, Sec. 14.4). Details are presented in table 3.

In each of the four curves significant deviations from linearity are shown. The tained by use of the curve approaches significance on day A and is highly significant on days B and C. On the last two days no significant deviations from the curve occurred. The curve fitted for the combined days shows a highly significant reduction of variation from the straight line, without significant deviation from the parabola. This information supplements that from table 3 in showing not only that linear regression fails to explain all between-concentration variation, but

Table 4.—Analysis of variance for testing significance of deviations from curved regression.

Variance of Probits	Mean Square			
	Day A	Day B	Day C	Combined Days
Sum of squares, deviations from linear regression	1.966 (4)[1]	1.074 (4)	2.066 (4)	1.326 (4)
Sum of squares, deviations from quadratic regression	1.664 (3)	.210 (3)	.540 (3)	.331 (3)
Reduction due to quadratic regression	.302 (1)	.086† (1)	1.526†(1)	.996† (1)
Mean square within classes (error)	.064 (10)	.033 (10)	.084 (12)	.090 (12)

[1] The number of degrees of freedom for each variance is stated after it in parentheses.
† Highly significant.

also that deviations definitely took the form of a gentle upward curve.

The slightly curvilinear nature of the concentration-mortality curve, observed in various sets of data, even when concentration figures are transformed to logarithms and percentages of mortality to probits, is thus confirmed strongly, by this material. Several adjustments were tried to see if linearity could be approached more closely. Mean probits for each of the three days were averaged to secure points at six concentrations. The absence of significant interaction of day and treatment made this a representative series. When plotted it gave the typical gentle curve. Several modifications of concentration were tried, including the square and cube roots and the powers 1/1.8, 1/2.2 and others. None gave linearity; some showed curvature in one part of the range and some in another. It seemed possible that modification could be applied to the percentage mortality rather than to the concentration. Logarithms of probits plotted against logarithms of concentration (suggested by O'Kane *et al.* 1934) came nearer linearity than did probits plotted against logarithms, but a trace of sigmoid curvature was still apparent. Use of modified "probits" based on skew frequency curves was tried, but gave little promise.

DISCUSSION.—This study makes it apparent that further investigation of the concentration-mortality curve may be justified. Two other methods might be suggested for further study to find a better adapted curve. One is the fitting of curves to the untransformed data. This may readily be done, and several curves will give a fairly good fit to any given set of data. Bliss (1935b) has suggested the equations $Y=a+bX^c$ and $Y=a+b(X-C)^2$, as usable. The senior writer has used $Y=a+b(\log X)+C(\log X)^2$, which gives a curve similar to the log-probit curve but without the lower bend, with a definite threshold, and usually with a 100 per cent mortality value. Dr. A. E. Brandt mentioned to the senior writer $\log Y=a+b \log X+C(\log X)^2$. These curves, however, do not have the convenience in fitting of the log-probit curve, and do not take into account, as it does, the frequency distribution of susceptibility among individuals.

The other method is to modify the basis of transformation. The preliminary attempts made by the writers and by O'Kane *et al.* (1934) have been discussed. After studying various published and unpublished data as well as the present material, the writers are of the opinion that the logarithmic transformation of concentration often fails to bring normality. Studies of modification of transformation would seem to be justified. Parker-Rhodes (1942) has suggested one modification which will need more study.

It seems likely that the log-probit transformation will be useful in many connections, but the assumption that it defines perfectly the dosage-mortality relation is very questionable. The use of extrapolation, in attempts to predict mortality at high concentrations, where sufficient numbers cannot be used to check the theory, seems especially dubious. The implied impossibility of increasing concentration sufficiently to secure complete mortality with certainty seems unreasonable. It is contrary to the known fact that modifying an environment sufficiently makes existence of a particular species impossible.

SUMMARY.—The concentration-mortality relation was studied, adult houseflies and pyrethrum sprays being used for this purpose. Tendencies noted repeatedly in the work of others suggested tests of several points. There was strong indication of a definite threshold of toxic concentration. Numbers of insects were insufficient for checking the significance of 100 per cent mortality at the highest concentration. The lower bend in the asymmetric sigmoid curve was not well defined. When spray concentrations were transformed to logarithms and percentages of mortality to probits, the data indicated significant and definite curvature. Linearity was positively disproved in this material. It seems likely that the log-probit transformation is useful but not perfect, that extrapolation should be discouraged, and that further study of the curve is justified.—12-18-42.

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New Developments in the Study of Ectoparasite Resistance

LEO KARTMAN, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*[1]

The subject of host-parasite relations has taken on a new aspect in the past two decades chiefly from more numerous studies into the complex phenomena of nutritional influences upon the susceptibility of the host to the ingress of certain of its parasitic forms. A great amount of work has already been accomplished in the attempt to demonstrate specific immune bodies as a reaction to protozoan, helminth, and arthropodan parasites. More recently many studies have been published on the attempt to correlate dietary factors with the relative intensity of endoparasitic development in the various host tissues.[2] Very little experimental work has been recorded on the relation of these nutritional variables to the ectoparasitic immunity of the host.

The intimate association of internal parasites with the life processes of the host inevitably leads to the hypothesis that the host's food must have some effect upon the economy of its parasites. It is not so easy to visualize a similar relationship in regard to external parasites. Nevertheless, it may be fair to assume that this type of causal relation may obtain for, at least, those forms which are obligatory ectoparasites.

Arthropods such as mites and the blood-sucking lice, which are in intimate contact with the skin and its products (a structure no less complex than that of the viscera), must be affected in some manner by significant changes in that organ. If certain dietary factors are the predisposing cause for important modifications in the hair, skin, or blood, then ultimately these changes may influence the host's ectoparasitic economy.

Perhaps one of the first concrete suggestions of a relation between diet and ectoparasite resistance was postulated by Searls and Snyder (1935) during the course of experiments to control lice on laboratory rats. Although they did not publish their observations at the time, these workers noted that rats in a generally poor nutritive state harbored more lice than rats apparently well fed.

Experiments designed to show the effects of a deficient diet on the ability of the laboratory rat to resist multiplication of the rat louse, *Polyplax spinulosa* Burm., were later conducted. A general, but indefinite, trend toward intensified pediculosis on rats fed a ground wheat ration as compared to rats on a complete ration was observed. It was also noted that the lice could be somewhat reduced by the addition of carotene in *Wesson oil* (carotene is pro-vitamin A) to the wheat ration (Kartman).[1]

[1] The author is indebted to Dr. W. Dwight Pierce, Curator of Entomology at the Los Angeles County Museum, for his suggestions and encouragement.

[2] *Cf.* James T. Culbertson's recent book, "Immunity Against Animal Parasites," New York, 1941; or the older work by W. H. Taliaferro, "The Immunology of Parasitic Infections," New York, 1929.

[1] Unpublished data, University of Wisconsin.

Further work with the rat louse showed a definite positive correlation between adequate amounts of vitamin A, supplemented to a vitamin A-free ration, and ectoparasite resistance (Kartman 1937). In this work albino laboratory rats were fed a basal vitamin A-free ration and the experiment was divided into two general periods based on the effects of the vitamin A factor. The foreperiod extended from the beginning of the experimental period until the depletion of vitamin A became evidenced by typical symptoms. The afterperiod extended from the end of the foreperiod to either the death of the rat or at the desired termination of the experiment. Superimposed infestations of lice from "reservoir" rats were initiated at the end of the foreperiod.

The rats were placed in the following experimental groups: *Group A*—at the end of the foreperiod these rats were infested with lice and maintained, during the afterperiod, at a very low vitamin A level by feeding each rat 3 gamma of carotene in *Wesson Oil* once per week.

Group B—at the end of the foreperiod these rats were infested with lice and maintained, during the afterperiod, at a high vitamin A level by feeding each rat 10 gamma of carotene in *Wesson Oil* three times per week.

Group C—the control rats were fed 10 gamma of carotene in *Wesson Oil* three times per week throughout the foreperiod and afterperiod and infested with lice at a time corresponding to infestations given to the othe groups.

Table 1 summarizes the data on the condition of the rats at the end of the foreperiod and at the termination of the afterperiod.

These purely qualitative observations were also substantiated when it was shown that rats maintained at a level of avitaminosis-A showed an average infestation of 1451.4 lice per rat; rats given the curative treatment for avitaminosis-A showed an average infestation of 28.2 lice per animal; the control rats revealed an average infestation of 12.5 lice each. Those rats which were maintained on a vitamin A-free ration until death or the termination of the experiment showed an average louse infestation per rat of about 120 times that on the control animals (Kartman 1942).

In addition to the work with vitamin A recent observations indicate that the vitamin B_2 complex is also connected with

Table 1

		Group A		Group B		Group C	
End of Foreperiod	Number of rats	15♂	20♀	15♂	12♀	10♂	10♀
	Avg. no. of days per rat	35.8	32.6	33.6	37.3	35.0	35.0
	Avg. original wt. per rat, grams	51.3	50.0	47.7	47.3	46.6	42.6
	Total avg. wt. change, grams	+55.1	+55.4	+52.2	+58.1	+106.2	+64.0
	Xerophthalmia	100%	100%	100%	100%	0%	0%
	Bristly fur	40%	15%	24%	0%	0%	0%
	Respiratory infection	33%	25%	60%	100%	0%	0%
	Paralysis (unsteadiness)	6%	0%	0%	0%	0%	0%
	Avg. lice given per rat	22.3		26.7		23.5	
End of Afterperiod	Avg. no. of days per rat	24.4	37.0	31.8	60.7	63.0	63.0
	Total avg. wt. change, grams	−6.7	−6.1	+38.4	+68.0	+84.0	+56.2
	Xerophthalmia	100%	100%	60%	0%	0%	0%
	Bristly fur	80%	95%	60%	0%	0%	0%
	Respiratory infection	100%	95%	60%	0%	0%	0%
	Paralysis (unsteadiness)	46%	55%	60%	0%	0%	0%
	Final observed louse infestation: none			20%			20%
	few	60%	25%	80%	100%	100%	80%
	many	20%	35%				
	severe	20%	40%				

The days for the control rats (Group C) were arbitrarily divided since these rats had no foreperiod or afterperiod. Total experimental time was 98 days.

Later work definitely confirmed the positive findings cited above (Searls & Snyder 1939).

ectoparasite resistance. Experimental work has shown that pediculosis was apparent on about 20 per cent of rats kept on a riboflavin-free diet for from eight to ten weeks. The lice were practically eliminated from the rat host by the therapeutic feeding of riboflavin (György 1938).

A very important point in connection with the riboflavin experiments is the fact that the majority of the rats with pediculosis were by no means weakened or inactive. Heavy louse infestations were not observed even in moribund rats ill with acrodynia (B_6 deficiency) or with progressive panmyelophthisis caused by a deficiency of the maturation factor. Even diseases such as pneumonia, lung and kidney abcesses, generalized sepsis, and diarrhea did not prepare the way for pediculosis, except in rats fed riboflavin-free diets.

A similar situation was not in evidence during the course of the vitamin A experiments. As a matter of fact, it was noted that certain rats with sufficient storage of vitamin A tended toward intensified pediculosis if ill with respiratory infections, diarrhea, abscesses, or generalized infections (Kartman 1937).[1] This would seem to indicate that riboflavin may possibily bear a more direct and specific relation to ectoparasite immunity manifestations than vitamin A. In this respect it has been suggested that since members of the vitamin B_2 complex are linked with sulphur metabolism, this may be the way in which riboflavin influences pediculosis (Chandler 1941).

Some work has already been done in an attempt to effect a resistance to chicken lice, fleas, and mites by the addition of commercial flour sulphur to chicken mash and by the feeding of sulphur in capsules (Emmel 1938, 1942). These experiments indicated that the ectoparasites were controlled by sulphur getting into the feathers from the chicken mash and not by the effect of sulphur swallowed by the birds. However, the results are too inconclusive since the sulphur was administered in only one form and no attempt was made to catalyze the action of the sulphur in the chickens by the addition of other chemical agents, among which riboflavin could have been tested. In this connection, Pierce has made the interesting observation that ferrous sulphate was excreted under the arm pits in profuse amounts after having been apparently absorbed through the skin during frequent handling.[2] It has also been found that if man swallows sulphur (a portion of which is excreted epidermally as H_2S) there is no particular effect on resistance to the human louse, *Pediculus humanus corporis* Deg. (Buxton 1939).

It is clear from the work cited that extremely little is known at present regarding the relation between specific dietary factors or vitamins and ectoparasite resistance. At best we are merely at the starting point for future work which may have considerable economic importance when we consider the many species of ectoparasites that are either directly harmful or are vectors of important diseases of man and domesticated animals.

Unfortunately certain results of the vitamin A experiments may have been too enthusiastically summarized giving vitamin A the main limiting role in regulating the resistance of the rat to its lice (Searls & Snyder 1939). This has given rise to the erroneous principle that "whereas a diet deficient in vitamin A increases susceptibility to infestations with lice, a diet containing an abundance of this vitamin will prevent or cure such infestations" (Eichhorn *et al.* 1942).

No work to date could actually warrant the above quoted statement and its presence in the 1942 Yearbook of Agriculture, designed for popular consumption, is a warning against too hasty conclusions. The addition of vitamin A to the rat diet has not been shown to effect a resistance to lice in general, but to cause a resistance under certain very limited and controlled experimental conditions. The formerly generally accepted conception that the administration of vitamin A will mitigate the severity of infections is being discredited for it has been shown that animals may die of an infection and still retain adequate amounts of vitamin A in the liver (Harrow 1941).

Work must be directed toward an explanation of whether the presence of vitamin A has a direct immunological effect upon ectoparasite resistance. Will a sick rat with adequate vitamin A stores resist its lice, or does the A factor work only in the presence of robust health? What is the possible relation between vitamin A and

[1] Unpublished data, University of Wisconsin.
[2] Pierce, W. D., in letter to author dated November 27, 1942.

the B_2 complex factors in respect to such an immunity? This latter question must be answered since it is now an uncertainty whether adequate or inadequate B_2 factors were originally supplied in the basal diet during the course of the vitamin A studies cited above.

Another problem to be considered concerns a possible relation between dietary factors and acquired and age immunity. Age immunity to ectoparasites in itself is a problem that has not yet been investigated as has age immunity to helminths, for instance. This factor may bear watching during the course of experiments to determine dietary effects.

The problem of skin changes and the effects of epidermal secretions and excretions in relation to diet and the ability of ectoparasites to multiply and obtain sufficient nourishment needs investigation. Many workers are of the general opinion that certain skin emenations have either an attractant or repellant effect upon parasitic species that feed on our through the skin. It may be that nutritive factors influence the amount and quality of skin products which are important to parasitic existence.

In most of the experiments cited the animals have been housed singly. This did not allow for louse migration which is most likely a factor in the increase or decrease of louse populations on individual rats under natural conditions. What significance this would have in conjunction with dietary factors and illness must be determined. The latter point may be of especial importance since it is a common observation that the rat louse will attempt to leave a moribund host.

It may also be of some significance to investigate the influence of texture, amount and weight of hair or fur upon the ectoparasite since certain avitaminoses have definite epidermal syndromes involving the hair. A high positive correlation has been discovered between the weight of human hair and the intensity of infestation with *Pediculus humanus humanus* L. (Buxton 1940).

Above all, quantitative data on the amount of vitamin in storage organs in relation to number, size, and vitality of ectoparasites must be studied. This will give an adequate basis upon which to build sound conclusions regarding the presence or absence of an actual specific immunity. The small amount of work that has been accomplished on this problem gives us enough definite clues to make it a promising and interesting field of investigation and perhaps not without some important economic prospects.—12-7-42.

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Cured sweetpotato tubers may now be shipped into California and Tennessee from sweetpotato weevil-infested areas if they have been fumigated with methyl bromide, according to revisions of quarantines of these States, which were put into effect in June 1943. There is a similar provision in the current quarantines of Georgia and Louisiana.

Cutworm and Armyworm Populations in Pasture Grasses, Waste Lands, and Forage Crops

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The literature pertaining to cutworms and armyworms contains many references to the importance of grasslands and waste areas in maintaining populations of these insects. So far as is known to the writer, no detailed study of such habitats has been made with the object of determining the relative abundance of cutworms and armyworms in different types of grasses and forage crops.

During the course of the writer's investigations of the phalaenid caterpillars infesting cereal and forage crops in the central Great Plains, the need for definite information on the sources of infestation became apparent, and tentative plans for such a study were drawn. It was not until 1937, however, that the work could be begun. By that year the need for information had increased with the introduction of soil-conservation practices such a strip cropping, contour farming, revegetation projects, and the like. Accordingly, a study of the cutworms and armyworms inhabiting pasture grasses, waste lands, and forage crops was initiated in the spring of 1937 and continued through the spring and early summer of 1940. The project was set up in cooperation with the Departments of Entomology and Agronomy of the Kansas Agricultural Experiment Station and formed a part of the Kansas Experiment Station project then designated as "115B, Insects Affecting Pastures and Lawn Grasses." The Bureau of Entomology and Plant Quarantine assumed responsibility for that phase of the work relating to cutworms.[1]

In general the plan of work consisted of (1) the selection for study of representative areas consisting of pastures with different types of vegetation and under different systems of management, typical waste areas, or important forage crops; (2) the development of suitable methods for determining relative abundance of the Phalaenidae occurring therein; and (3) a study of the cutworms and armyworms inhabiting the areas selected for the studies.

Areas Selected for Study.—After an intensive survey of the country in the vicinity of Manhattan, Kan., 14 areas were chosen as typifying the pastures, waste lands, and forage crops of the locality where the more important species of grasses were growing in as nearly pure stands as could be found under natural conditions. Alfalfa and sweetclover were chosen to represent the forage crops. These areas designated as habitats, were all within 15 miles of Manhattan. Their characteristics are outlined in the following paragraphs. The habit of growth and use of the grass species were taken from a report of the Kansas State Board of Agriculture by Gates (1937). Habitats 1, 8, and 9 also have been utilized in the study of other grassland insects and the results reported by Wilbur & Sabrosky (1936) and Wilbur & Fritz (1940).

1. Little barley (*Hordeum pusillum* Nutt.). Winter annual, maturing in June, 4 to 14 inches tall. Of some forage value before maturity, but mostly a weed. This pasture was on a gently sloping hillside and had been seeded to Kentucky bluegrass (*Poa pratensis* L.) some years previously, but little barley had invaded the area concurrent with drought conditions and by 1937 had formed a dense cover almost supplanting the bluegrass.

2. Bluegrass (*Poa* sp., probably *pratensis* L.). A sod-forming perennial, 12 to 40 inches tall. This habitat consisted of a roadside strip of bluegrass which had become established under a row of black walnut trees. The trees were removed early in 1939 leaving the grass exposed to the full sunlight, and by the spring of 1940 the stand was beginning to become thin as a result.

3. Sweetclover (*Melilotus* sp.). Some 25 varieties growing in test plots were included in this habitat. New plantings to replace the old were put into adjacent plots each year.

4. Overgrazed pasture. This pasture, adjacent to habitat 13, consisted of a

[1] Credit is due D. A. Wilbur, of the Kansas Agricultural Experiment Station, for assistance in the planning and execution of the project.

rather steep, rocky hillside and was selected because of its badly overgrazed condition at the beginning of this study. The native perennial grasses had been largely supplanted by a mixture of little barley and various coarse weeds such as blue vervain, *Verbena* sp., and ironweed, *Vernonia* sp. In 1939, however, with less intensive grazing, certain of the perennial grasses reappeared, and by the spring of 1940 the dominant grass was side-oats grama, *Bouteloua curtipendula* (Michx.), Torr. with a moderate amount of buffalo grass, *Buchloe dactyloides* (Nutt.), Engelm. in the lower portion of the field.

5. Alfalfa, *Medicago sativa* L., old stand. This field had been in alfalfa for about 8 years when observations were begun in 1937, and although the stand was thin, there was but little grass and weed growth.

6. Alfalfa, new stand. Seeded in the fall of 1936, an excellent stand of young alfalfa plants was on the ground in the spring of 1937 and persisted throughout the period of observations.

7. Native hay meadow, I. The vegetation here was composed of a mixture of native prairie grasses, principally little bluestem *Andropogon scoparius* Michx., big bluestem, *A. furcatus* Muhl., and prairie Junegrass, *Koeleria cristata* (L.), Pers. together with other herbage such as sensitive brier, *Leptoglottis* sp., sunflower, *Helianthus* spp., and evening primrose, *Oenothera* spp. The meadow was cut annually for the wild-hay crop. The field was located at the edge of a narrow valley at the point where the rise to the upland begins. It was bordered by wheat land on three sides and on the fourth by a hillside pasture.

8. Little bluestem, *Andropogon scoparius* Michx. A bunchgrass 20 to 60 inches tall. Of very great value for both pasture and hay. One of the most abundant grasses in the prairie region, essentially immune to drought except in such hot, dry summers as 1934 and 1935. This pasture was a typical upland prairie of the region, known as bluestem pasture, with the grass in a thrifty condition both as to stand and growth. The vegetation consisted of mixed grasses in which little bluestem was dominant, with big bluestem next in abundance. There was no evidence of overgrazing.

9. Bromegrass, *Bromus inermis* Leyss., thin stand. A sod-forming perennial, 20 to 40 inches tall. Cultivated for hay and pasture. This pasture was on a gentle slope and had been seeded to a mixture of orchard grass, *Dactylis glomerata* L., and bromegrass. At the beginning of this study in the spring of 1937 the orchard grass had disappeared, and the stand of bromegrass was thin and closely grazed. The land was plowed in the fall of 1937 and reseeded to bromegrass, but no stand was secured. The field then remained bare and idle until the fall of 1938, when it was again seeded to bromegrass, but again no stand resulted. In the spring of 1939 the field was seeded to oats for pasture and was grazed heavily, and in the fall of that year was seeded to winter wheat, which was used for pasture in the spring of 1940.

10. Wild rye, *Elymus virginicus* L. A tufted perennial, 20 to 50 inches tall, which makes fairly good hay if cut early. This stand of wild rye was in a grove of trees growing along a creek bank, and constituted one of the large areas of this grass in the vicinity. It was very heavily grazed in 1938 and flooded in 1939.

11. Dropseed, *Sporobolus heterolepis* A. Gray. A densely tufted perennial, 15 to 36 inches tall, foliage wiry and tough. Of little value as a forage grass. This area, an old, partly filled-in channel of the Kansas River, cut off by floods many years ago, had become revegetated by natural processes. The vegetation consisted of a tangled mass of dropseed and various weeds. The soil between the plants was covered with a thick layer of decaying litter.

12. Bromegrass, *Bromus inermis* Leyss. This habitat consisted of an almost pure stand of this grass growing along the roadside and bordered a cultivated field. It was not grazed during the period of this study.

13. Native hay meadow, II. This habitat was similar in vegetative characters to the meadow described under habitat 7, but was larger and was bordered by pastures and a narrow belt of trees along a small stream.

14. Panic, or switchgrass, *Panicum virgatum* L. A perennial growing in large, coarse bunches or clumps, 3 to 6 feet tall. A good hay grass if cut young, but not important as a forage grass because of its coarse texture, especially after July 1. This habitat comprised a large area of waste land on the south bank of the

Kansas River. There was a small admixture of cordgrass, or sloughgrass, *Spartina* sp., and Indian grass, *Sorghastrum nutans* L. Nash., and also some of the coarser annuals such as sunflowers and giant ragweed, *Ambrosia trifida* L. The area was burned over in both 1939 and 1940.

THE SACK-TRAP COLLECTION METHOD.—A method of collecting the larvae under burlap sack-traps was devised so that the comparative abundance of the cutworms and armyworms occurring in the various described habitats could be determined. These traps consisted of 4 thicknesses of burlap 1 foot square pegged down with nails, this number of thicknesses being employed to insure complete exclusion of light under the traps. Twenty-five of them were placed in each of the habitats selected for study. The traps were spaced about 30 feet apart in either a circular or an L-shaped arrangement, which facilitated tending them when the vegetation had attained a height of a foot or more. In some of the habitats the vegetation reached a height of nearly 6 feet.

The larvae of practically all the species involved in this study have the habit of hiding under objects during the day. By taking advantage of this habit through the use of the sack-trap method of collection, it is believed that a reliable comparison of the abundance of the different species in the various habitats was obtained. Traps of this sort may give an inflated estimate of the actual population, owing to concentration under the trap, but nevertheless are valuable in detecting differences between habitats.

Observations were begun in March or early in April of each year, depending on weather conditions, and were continued until late in June, previous work having shown that this was sufficiently late. The traps in each of the habitats were examined at intervals of from 3 to 10 days, and the number and species of cutworms and armyworms hiding underneath were recorded at each examination. The larvae so found, which varied greatly in the stage of larval development, were removed to the laboratory for rearing. Early in the season overwintering larvae were taken, and at that time they were half-grown or larger. As the season progressed mature overwintered larvae were found, and these were then replaced by the small larvae of species that overwinter in the egg stage, second instars being taken in abundance. By observing the larval instars of trapped specimens it was thus possible to trace the seasonal development of the various species.

RESULTS.—During the 4-year period totals of 24 species and 4687 specimens of cutworms and armyworms were taken from the traps in the 14 habitats. These species are listed below in the descending order of their abundance.

Species	*Per cent of Total*
Feltia subgothica (Haw.), dingy cutworm	20.9
Peridroma margaritosa (Haw.), variegated cutworm	16.5
Nephelodes emmedonia (Cram.), bronzed cutworm	15.0
Agrotis venerabilis Walk.	13.3
Chorizagrotis auxiliaris (Grote), army cutworm	13.3
Agrotis gladiaria Morr.	12.6
Cirphis unipuncta (Haw.), armyworm	6.1
All other species as listed below	2.3
Leucania phragmatidicola Guen.	
Protoleucania albilinea Hbn., wheat-head armyworm	
Agrotis ypsilon (Rott.), black cutworm	
Amathes c-nigrum (L.), spotted cutworm	
Amathes badinodis Grote	
Lacinipolia meditata (Grote)	
Euxoa messoria (Harr.), dark-sided cutworm	
Prodenia ornithogalli (Guen.), yellow-striped armyworm	
Rusina bicolorago (Guen.)	
Caenurgina erechtea (Cram.), forage looper	
Plathypena scabra (F.), green clover worm	
Ceramica picta (Harr.), zebra caterpillar	
Orthodes incincta (Morr.)	
Autographa biloba (Steph.)	
Autographa falcifera (Kirby)	
Autographa brassicae (Riley), cabbage looper	
Adita chionanthi (A. and S.)	

The first seven species in the list make up nearly 98 per cent of the total number taken, and include nearly all the important species occurring in the vicinity of Manhattan.

The comparative abundance of cutworms and armyworms in the different habitats is given in table 1. Three habitats—little barley, bluegrass, and sweetclover—were outstanding as places apparently favored, 53 per cent of the total number having been taken from these habitats alone. Thus it appears that, with the exception of areas in which little barley and bluegrass are dominant, native grass pastures, hay meadows, and waste lands are of little consequence as breeding areas

for cutworms and armyworms. The overgrazed pasture ranked fourth in abundance of cutworms and armyworms. Overgrazing had reduced almost to the vanishing point the perennial grasses normally present, and these had been replaced by little barley, thus creating a favorable habitat.

The distribution of the seven dominant species and their comparative abundance in the different habitats are given in table 2. The outstanding features are that 84 per cent of the bronzed cutworms were found in bluegrass and that 74 per cent of the variegated cutworms occurred in sweetclover. The other species were more generally distributed, although, with the exception of the dingy cutworm, they exhibited a preference for little barley. The dingy cutworm, even though widely distributed in the region, is very rarely present in large numbers in cultivated crops, and therefore passes practically unnoticed as a species of economic importance.

With regard to the seasonal occurrence of the most abundant species, *Feltia subgothica*, *Agrotis venerabilis*, *Agrotis gladiaria*, and *Chorizagrotis auxiliaris* were most abundant in March and early in April. *Nephelodes emmedonia* attained its greatest density late in April and early in May. *Peridroma margaritosa* and *Cirphis unipuncta* reached their peak of abundance in June. Observations were continued until November in 1937, but so few cutworms and armyworms were taken after July 1 that the results did not justify the time and effort expended in making the examinations.

Wide annual fluctuations in the abundance of cutworms and armyworms were noted during the period covered by this study. Of the total number of Phalaenidae recorded during the four seasons, 31 per cent were taken in 1937, 57 per cent in 1938, 4 per cent in 1939, and 8 per cent in 1940. The scarcity of cutworms and army-

Table 1.—Distribution and comparative abundance of cutworms and armyworms in different habitats, Manhattan, Kan., 1937–1940, inclusive.

Habitat Type	Per Cent of Total Phalaenidae	Most Abundant Species, in Order of Abundance
1. Little barley pasture	20.9	*Agrotis gladiaria* *Agrotis venerabilis* *Chorizagrotis auxiliaris* *Feltia subgothica*
2. Bluegrass, roadside	16.8	*Nephelodes emmedonia* *Feltia subgothica* *Cirphis unipuncta*
3. Sweetclover	15.4	*Peridroma margaritosa* *Feltia subgothica* *Agrotis venerabilis*
4. Overgrazed pasture	11.5	*Feltia subgothica* *Chorizagrotis auxiliaris* *Agrotis venerabilis*
5. Alfalfa, old stand	6.9	—
6. Alfalfa, new stand	4.4	—
7. Native hay meadow, I	4.3	—
8. Little bluestem pasture	4.2	—
9. Orchard-brome pasture	4.0	—
10. Wild rye, waste land	3.9	—
11. Dropseed, waste land	3.3	—
12. Brome, roadside	1.9	—
13. Native hay meadow, II	1.7	—
14. Panic grass, waste land	0.9	—

Table 2.—Distribution of the seven most abundant species of cutworms and armyworms in differerent habitats, Manhattan, Kan., 1937–1940, inclusive.

	Distribution of the Different Species, Per Cent of Total						
Habitat Type	*Feltia subgothica*	*Agrotis venerabilis*	*Agrotis gladiaria*	*Chorizagrotis auxiliaris*	*Nephelodes emmedonia*	*Peridroma margaritosa*	*Cirphis unipuncta*
1. Little barley pasture	14.6	37.4	49.6	32.0	1.4	0	31.0
2. Bluegrass, roadside	11.1	1.9	0.7	1.4	83.7	0.3	16.3
3. Sweetclover	5.4	7.5	0.4	2.6	0	74.4	1.9
4. Overgrazed pasture	18.3	9.4	18.9	26.6	0.2	1.1	1.9
5. Alfalfa, old stand	9.0	3.8	2.2	19.7	0	8.9	0.8
6. Alfalfa, new stand	1.1	6.6	3.7	4.2	0	11.7	2.7
7. Native hay meadow, I	9.8	6.3	8.7	0.2	0	0.9	1.9
8. Little bluestem pasture	5.7	7.9	6.7	7.9	0	0	0
9. Orchard-brome pasture	4.0	7.9	5.2	4.2	0	0.7	11.7
10. Wild rye, waste land	1.4	4.5	0.2	0	12.5	0.3	14.4
11. Dropseed, waste land	11.1	1.0	0.4	0	0.3	1.6	5.3
12. Bromegrass, roadside	2.7	3.5	0.4	0.3	1.1	0	8.7
13. Native hay meadow, II	2.7	2.1	2.9	0.9	0.8	0.1	1.9
14. Panic grass, waste land	3.1	0.2	0	0	0	0	1.5

Table 3.—Parasitization and disease in cutworms and armyworms taken from pasture grasses, waste lands, and forage crops, Manhattan, Kan., 1937 and 1938.

Species	Year	Number Observed	Parasitization			Death by Disease	Total Mortality
			By Hymenoptera	By Diptera	By Nematodes[1]		
			Per cent	Per cent	Per cent	Per cent	Per cent
Feltia subgothica	1937	486	15.6	2.3	0	3.1	21.0
	1938	237	6.8	0.4	0	3.0	10.2
Agrotis venerabilis	1937	171	1.2	0	1.2	2.3	4.7
	1938	212	0.5	0.9	1.4	20.8	23.6
Agrotis gladiaria	1937	119	5.3	0	0	0	5.3
	1938	207	6.3	0	0.5	10.6	17.4
Chorizagrotis auxiliaris	1937	0[2]	—	—	—	—	—
	1938	422	9.0	9.0	0	3.6	21.6
Nephelodes emmedonia	1937	243	0	0	0	6.6	6.6
	1938	180	0	0	0	42.2	42.2
Peridroma margaritosa	1937	402	6.0	4.2	0	3.2	13.4
	1938	102	52.0	7.8	1.0	13.7	74.5
Cirphis unipuncta	1937	121	51.2	0	0	2.5	53.7
	1938	52	50.0	9.6	0	1.9	61.5

[1] It was not determined whether the nematodes were primary parasites or merely scavengers appearing after the death of the host.
[2] No larvae of *Chorizagrotis auxilaris* were taken in 1937.

worms in 1939 was in a great measure due to an epidemic in the spring of 1938 of an undetermined disease, which caused rapid liquefaction of the larvae and decimated the populations of all species before the larvae reached maturity.

PARASITIZATION AND DISEASE.—To obtain information on the effect of parasitization and disease on the abundance of cutworms and armyworms occurring in the study areas, a large number of the larvae taken were reared individually in salve tins partly filled with sterilized soil. The results obtained from these rearings in 1937 and 1938 are presented in table 3. Those for 1939 and 1940 are not included, as the scarcity of larvae rendered the data of little value.

It may be seen that, with the exception of the dingy cutworm, there was a decided increase in parasitization and disease in 1938 over that of 1937. The percentage mortality shown in the table is probably lower than was actually the case under field conditions, as many of the larvae in the reared series were collected before disease had become widespread and parasites had attained their full effectiveness. Field observations indicated that these two factors were largely responsible for the reduction of the mature larval population to a very low level in the spring of 1938. Certain species, such as the armyworm and the variegated cutworm, appear to be particularly susceptible to parasite attack, while others, notably the bronzed cutworm, appear to be especially subject to disease.

The incidence of parasitization and disease, based on the periodic collections of

Table 4.—Incidence of parasitization and disease in cutworms and armyworms taken from pasture grasses, waste lands, and forage crops, Manhattan, Kan., 1937 and 1938.

Collection Period	Parasitization and Disease, Per Cent					
	Nephelodes emmedonia		*Peridroma margaritosa*		*Cirphis unipuncta*	
	1937	1938	1937	1938	1937	1938
March 11–20	—	0	—	—	—	—
March 21–31	—	9.4	—	—	—	—
April 1–10[1]	—	—	—	—	—	—
April 11–20	0	48.4	—	—	—	—
April 21–30	5.0	74.1	—	—	—	—
May 1–10	6.5	—	—	28.6	—	—
May 11–20	15.4	—	0	33.3	11.1	0
May 21–31	—	—	11.0	78.8	17.1	61.1
June 1–10	—	—	17.2	93.0	74.7	60.0
June 11–20	—	—	—	—	—	87.7

[1] Heavy snows during this period in 1938 made field work impossible.

larvae, increased progressively with the advance of the season in both 1937 and 1938 and was much greater during the latter year, as shown in table 4.

No satisfactory technique for inducing emergence of the adult parasites was developed, and consequently a large number could be determined only as to order. In the following list only those parasites which could be assigned to genus or species are included. The identifications were made by specialists of the Division of Insect Identification, Bureau of Entomology and Plant Quarantine.

Feltia subgothica, the dingy cutworm:
HYMENOPTERA: *Liothorax melanocera* Ashm.; *Berecyntus bakeri* var. *exuoae* Gir., *Microplitis feltiae* Mues., *Rogas* sp., *Rogas*, n. sp., *Ophion* sp.
Agrotis venerabilis:
HYMENOPTERA: *Ophion* sp., *Berecyntus* sp.
Agrotis gladiaria:
HYMENOPTERA: *Microplitis feltiae*, *Exetastes obscurus* Cress., *Ophion* sp., *Paniscus* sp., *Apanteles griffini* Vier.
Cirphis unipuncta, the armyworm:
HYMENOPTERA: *Apanteles militaris* (Walsh).
Peridroma margaritosa, the variegated cutworm:
HYMENOPTERA: *Ophion ancyloneura* Cam., *Ophion* sp.
DIPTERA: *Archytas* sp.
Chorizagrotis auxiliaris, the army cutworm:
HYMENOPTERA: *Microplitis feltiae* Mues., *Ophion* sp., *Ophion*, n. sp., *Apanteles griffini*, *Exetastes lasius* Cush., *Exetastes* sp., *Paniscus ocellatus* Vier., *Meteorus vulgaris* Cress.
DIPTERA: *Phorocera claripennis* (Macq.).

AMOUNT OF DAMAGE.—No satisfactory method of evaluating the damage caused by cutworms and armyworms to the various types of grasses and forage plants was developed during the course of this study. Where growth was rapid and the vegetation was not overgrazed, a dense population of cutworms had but little visible effect on the amount of feed available to livestock, but under conditions of drought and resultant slow growth a comparatively light population had a marked effect in reducing the already limited amount of feed. In one instance a small population of the armyworm completely defoliated the wild rye study area, while at the same time a rather dense population of the bronzed cutworm in the bluegrass plot caused no apparent damage. In the little barley pasture, the most prolific source of cutworms and armyworms discovered in this study, there was never any visible evidence of injury. In 1937 the variegated cutworm almost completely defoliated the sweetclover plot, greatly reducing the seed yield, and threatened to do so again in 1938 until their numbers were materially reduced by parasites and disease.

SUMMARY.—The abundance of cutworms and armyworms in 14 types of pasture grasses, waste lands, and forage crops in the vicinity of Manhattan, Kan., was studied during the 4-year period of 1937 to 1940, inclusive. A burlap-sack trap method devised for estimating the comparative abundance of cutworms and armyworms proved satisfactory as a means of determining differences in abundance in the various habitats under observation. A total of 24 species of cutworms and armyworms was found inhabiting the different types of pastures, waste lands, and forage crops. Only 7 of the species were taken in abundance during the 4-year period, and these constituted 98 per cent of the total number collected. Cutworm and armyworm abundance was consistently low in well-managed bluestem pastures, native hay meadows, and waste lands such as the dropseed and panic grass areas included in this study. Only three of the habitats selected for study, namely, little barley, bluegrass, and sweetclover, proved to be outstanding as apparently favored places, 53 per cent of the total number of cutworms and armyworms having been taken in these three habitats alone. Parasites and disease played an important part in reducing abundance to a low level in 1938. The damage caused was not always in direct ratio to the abundance of the caterpillars, but was largely governed by the ability of the vegetation to outgrow the effects of the feeding.—1-2-43.

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Evaluation of a Field-Control Program Directed Against the Beet Leafhopper

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Since 1931 the companies processing beet sugar in central California have engaged in a large-scale control program against the beet leafhopper, *Eutettix tenellus* (Baker), in this area, spending sums ranging from $10,000 to $20,000 a year. This program consists of spraying against the leafhopper on its chief summer host, russian-thistle, *Salsola pestifer* A. Nels, as well as controlling this host, and of spraying leafhopper aggregations on fall and winter host plants in foothill areas (Cook 1933, 1934). This paper discusses possible methods of evaluating the fall and winter spray work.

THE PROBLEM.—The beet leafhopper produces three or more broods each year in the valley-bottom areas of the San Joaquin and Sacramento Valleys during the period between May and October. The last brood, maturing in October, leaves the ripening summer hosts and drifts away. Many of these leafhoppers find their way to the plains and foothills of the Coast Range bordering the west side of the two valleys. Since the summer is practically rainless, the only green plants available in October are perennials and late-summer annuals growing on the plains, in wash bottoms, and upon slopes. The leafhoppers must subsist upon these "hold-over" hosts until the rains germinate the winter annuals. This usually takes place in late November and December, and then the leafhoppers soon move to patches of winter-annual hosts on the south slopes or in other favorable locations where the general vegetation is scanty. In February the females begin to lay their eggs. One or two spring broods are produced in these locations, and the resulting leafhoppers move out into the bottoms of the San Joaquin and Sacramento Valleys in April and May.

Although the Sacramento Valley is infested with beet leafhoppers during the spring, summer, and fall, very few leafhoppers survive the winter there, and that valley must be reinfested each spring with migrants from the San Joaquin Valley (Severein, 1933). Most of the sugar beets are grown in the Sacramento Valley, and the importance of the San Joaquin Valley breeding areas diminishes with their distance from the sugar beet fields. Accordingly, the control work is designed to reduce leafhopper populations and weed host plants to their lowest possible levels in the northern part of the San Joaquin Valley and then to carry the work as far south as time and funds permit.

The fall and winter spraying consists of the treatment of all accessible concentrations of leafhoppers upon hold-over hosts and upon winter annuals. The spray used, a diesel fuel oil containing the extract of a half pound to a pound of pyrethrum flowers per gallon, is applied with a special atomizer nozzle at the rate of about 5 gallons per acre. The spray is effective, regularly killing practically every leafhopper hit, and the efficiency of application is such that kills of 90 per cent or more of the leafhoppers found in sprayed areas are regularly obtained.

POSSIBLE METHODS OF EVALUATION.—Because of the nature of the control operations, and because of the migratory habits of the leafhopper, it is not feasible to leave unsprayed areas as checks. A small unsprayed area would be useless, as the leafhoppers shift about during the entire winter, and the population remaining on an unsprayed area would be distributed over the surrounding sprayed areas before spring. It would be risky to leave a large area unsprayed, as the leafhoppers produced on such an area in the following spring might be sufficiently numerous to cause considerable damage. Consequently the value of the spray work must be estimated by indirect methods.

As the object of the spraying is to reduce the number of leafhoppers reaching the beet fields in the following spring, counts of the leafhoppers in the beet fields in springs following spraying might be compared with similar counts in springs following no spraying. Also, as the damage is done by the curly top disease, for which the beet leafhopper is the only known vector, counts of the percentage of plants infected by curly top found in beet fields in years following spraying might be com-

pared with those in years following no spraying. Similarly, if curly top is the chief cause of fluctuation in beet yields, the yields of beets might be compared for the two sets of years. Finally, theoretical computations, based upon field estimates of insect population and spray mortality, might be used to estimate what might have happened in certain areas if the leafhoppers had not been controlled.

SPRING LEAFHOPPER POPULATIONS FOLLOWING AND IN THE ABSENCE OF SPRAYING.—This method of evaluation would be very useful if it could be shown that the control work was the only factor affecting the size of the beet leafhopper population comprising the spring movement, or if data were available for evaluating other important factors. The spring brood is the progeny of the last summer brood of the preceding year. The size of the leafhopper population comprising this summer brood depends upon the abundance of available host plants and the concentration of leafhoppers on these hosts. Further, the summer brood is diminished by fall mortality during and after migration and by winter mortality after the winter host plants are reached. None of these factors have been accurately measured for the period preceding the spray work and can only be guessed at. Also, reliable spring-population data for the entire beet area are available only for the period 1930 to 1941, of which only 1930 and 1931 precede the spray operations. Scanty information is available regarding summer and fall populations and winter mortality in 1930 and 1931. Since this information is not sufficient to show whether these may be regarded as years of high, moderate, or low leafhopper populations, it is risky to use them in comparison with later years. For these reasons it is not feasible to use the density of the spring population in the beet fields as a direct measure of the value of spraying.

CURLY TOP INCIDENCE.—Curly top is carried into the beet fields in the spring by the beet leafhopper, and the easily recognized symptoms can be found within a month after the plant is inoculated. Since the incidence of curly top depends upon the leafhoppers, the percentage of plants showing symptoms 3 or 4 weeks after the spring migration should be a measure of the incoming leafhopper population. Romney (1939) has used fall counts of the percentage of plants infected by curly top as an indicator of leafhopper populations in New Mexico and Colorado. In the present case the use of the curly top-disease counts as a basis of evaluating the spray program is subject to the same disadvantages as the use of leafhopper-population counts. In addition, the percentage of plants infected by curly top depends not only upon the number of leafhoppers entering the beet fields but also upon the percentage of these leafhoppers carrying the curly top virus. Only a few determinations of this point have been made, but the percentage of viruliferous leafhoppers varied so erratically as to make the use of curly top data open to serious question. Also, as in the case of leafhopper-population data, reliable figures are available for only two seasons preceding the spray work.

THEORETICAL COMPUTATIONS OF CONTROL WITHIN A SMALL AREA.—Assuming that a certain proportion of the overwintering female leafhoppers is killed by spray during the fall, what is the effect upon the forthcoming spring broods? For the purposes of this discussion it will be assumed that the field methods used to determine the natural and spray mortality are reliable, as the problem of their accuracy is too involved to be brought into this discussion.

A superficial consideration of the question leads to the conclusion that a spray mortality of 80 per cent, for example, should be followed by a reduction of 80 per cent in the size of the following spring broods. However, further analysis would indicate that this is true only if it can be shown that the population killed by spraying is a random sample of the entire fall population, and that the spring reproduction of the survivors is not favored by the release of population pressure involved in the destruction of a large part of the hibernating brood.

With regard to the first point, if the spray work does not destroy a random sample of the fall population, then those females killed must be either stronger or weaker than the average. If they tend to be stronger than the average, the survivors will be weaker than average, will undergo a higher winter mortality than average, and will produce a smaller than average spring brood. Since no check plots are available, this point cannot be determined directly, and the value of the

spray work must be estimated from the performance of the survivors in sprayed areas. Hence, if the remaining population has a lower rate of reproduction than the average of the general fall population, the spring brood will be proportionately smaller than normal, and when this small reproduction is used to calculate the theoretical size of the entire brood, if no spraying had been done, the entire brood is underestimated. In other words, if the spray tends to kill the stronger females, then the figures obtained by using the spring reproduction of the survivors to estimate the value of the control work are biased against the spraying. Conversely, if the spray tends to destroy female leafhoppers weaker than average, the figures obtained from the spring reproduction of the survivors are biased in favor of the spraying. In the present instance, the field evidence tends to indicate that the females killed by the spray are either a random sample of the entire population or possibly somewhat stronger than the average because of their position on favorable host plants at the time of spraying. This would mean that the figures obtained might have a bias against the spray work, but would not favor it.

With regard to the second point, or the effect of release of population pressure upon spring reproduction: The area of spring breeding hosts is limited. Such a large population of leafhoppers might survive the winter that all available host plants would receive more eggs than they were capable of maturing to the adult stage. Under such conditions a reduction by spraying would have no effect upon the spring population until the population of overwintering females was reduced below the saturation point for the breeding area. This condition is chiefly of theoretical interest, as only a few times, and in small areas, have populations of spring forms been observed that approached the point of saturation of available hosts.

Although complete saturation of the environment is a phenomenon of rare occurrence, yet local saturation of the most favorable environment, accompanied by high mortality and overflow of nymphs into less favorable environments, is a situation that might easily happen. Under these conditions a hundredfold potential spring reproduction might be reduced to twentyfold or less. The small population left after spraying would probably attain a higher reproduction than the general average in the absence of spraying.

The results of combining the factors considered above may become complicated. So far as the beet leafhopper is concerned, it is possible that the spray tends to eliminate the stronger females, but the increased rate of reproduction of the survivors might counterbalance this factor, so that the net reproduction of the spring brood would tend to be nearly normal. To summarize this part of the discussion, it would appear that figures for theoretical spring reproduction based upon the performance of the survivors should be either unbiased, or biased against the control work.

SUGAR BEET YIELDS.—If it could be shown that curly top was the principal factor affecting sugar beet yields in the area of study during the period in question, beet yields might be useful as an index of leafhopper and curly top damage. Carter (1930) has used beet yields as such an index for southern Idaho. Beet yields are available for the Sacramento and San Joaquin Valleys for the period 1917–40, giving a period of 15 years previous to spraying and 9 years since sprayng started. Several factors interfere with their use for evaluating the spray program. As yield is assumed to depend upon curly top, and the incidence of curly top disease depends upon leafhopper populations, the use of yield is subject to all the drawbacks suffered by other measures. In addition, beet yields are known to have been affected by factors other than curly top during the period in question. The area within which the beets are grown has changed greatly during the period. The acreage harvested has ranged from 475 acres in 1919 to 86,456 acres in 1936. After the severe outbreak of 1925, the recommendations of Severin and Schwing (1926) were followed, and between 1926 and 1932 very few beets were planted later than March 15 because of the risk of curly-top damage. Since 1932 an increasing acreage of late-planted beets has been grown. Strains of beets resistant to curly top were first widely used in this area in 1937 and have been used almost exclusively since that time. Cultivation and irrigation practices have been greatly improved during the past 24 years. All these factors have affected the yield, and, while some

of them can be evaluated, others cannot, because of uncertainty as to when and how widely they were followed. Consequently beet yields are of limited value for assessing the spray work.

Control Over Large Areas.—Up to this point the analysis has been concerned with estimating the probable effects of a known spray mortality upon the ensuing spring reproduction. When larger areas are considered, the factors of size and location of each individual breeding area assume importance. Although the exact distribution of leafhoppers following a migration is not known, it may be assumed that the contribution of a breeding area to the beet fields will be directly proportional to the number of leafhoppers present in that area, and will be inversely proportional to some function of the distance of that area from the beet fields. For equal contributions, an area 100 miles from beets would have to contain at least 100 times as many leafhoppers as an area 1 mile from the same beets. In a comparison of two areas at different distances from the beet fields the important figures to consider are the actual leafhopper populations left after spraying and not the percentages killed by spray. On the basis of intensive field studies each important area may be assigned a maximum population that may be regarded as safe. Any increase beyond this value results in danger to the beet fields. If the control work keeps populations in each of these areas below the danger point for that particular area, the exact percentage killed is unimportant.

Complete evaluation of the spray work does not involve merely the determination of percentage of female leafhoppers killed, the evaluation of the effects of this kill upon the spring brood, and the estimation of the remaining populations in terms of their approach to the danger point for the area. It is also necessary to estimate whether the progeny of the entire fall brood in a given area would have been sufficient to cause damage in the absence of spraying. This final point is the one open to the greatest question, as it is based upon estimations of percentage kill, of performance of survivors, and of total surviving populations. Each of these is subject to error, and if the errors are cumulative, the final result may be greatly in error.

SUMMARY.—The evaluation of a field control program against the beet leafhopper in central California is considered. Comparisons of leafhopper populations or consequent curly top disease damage following or in the absence of spraying are not feasible, and yield comparisons on this same basis are also questionable.

A method is proposed for the evaluation of the control by estimating the potential spring brood from the performance of the females that survived the spraying. Selective killing of stronger- or weaker-than-average females tends to bias the results against or in favor of the control, respectively. Killing a large part of the fall population releases pressure and tends to favor the reproduction of the survivors, causing a bias in favor of control.

The contributions of spring leafhoppers from breeding areas at various distances from beet fields are assumed to be proportional to their total populations and inversely proportional to their distances. A maximum safe population may be set for each breeding area, below which control must reduce the population to be effective. Control is ineffective if it be shown that the total population before spraying was so small that no damage would have resulted from their progeny.—1-26-43.

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Laboratory Tests of Termite Shields

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The use of metal termite shields as a supplement to good construction has been recommended for a number of years by the Bureau of Entomology and Plant Quarantine. When used as recommended they give additional protection, but the many instances of poor installation have shown the importance of more detailed information on the protection they afford. In 1939, investigations were begun on the Harrison Experimental Forest, Saucier, Mississippi, to determine the fundamental principles that influence the effectiveness of shields, and to determine whether a simpler and more easily installed type of shield would be as effective as the type now recommended.

The data presented are the results of laboratory tests of different types of shields with brief comments on the most practical types. These data are restricted to the conditions of the tests, which were purposely made as nearly optimum as possible for termite activity. The results are not conclusive enough to furnish definite information on many phases of the problem, but they give indications of what may be expected of shields used under service conditions exceedingly favorable for the termites.

COLLECTING TECHNIQUE.—Logs or stumps containing large colonies of the eastern subterranean termite *Reticulitermes flavipes* (Kollar) were sawed up, split into small pieces, and jarred over a sifter of quarter-inch mesh screen so that only the termites and the smaller pieces of debris dropped into a shallow tray the corners of which were slightly open. This tray was set in a second shallow tray in the bottom of which had been placed a few small pieces of thin wood, and strips of moist blotter folded to make small corrugations. Both trays were placed in a warm location where the source of heat was above them. As the debris dried, the termites left this tray and collected under the moist paper. The termites were jarred from the paper through a large funnel and collected in a graduated glass cylinder. By measuring living termites collected by this method, etherizing them, and counting them it was found that each unit of 5 cc. contained approximately 1000 mature workers.

TEST METHODS.—Two kinds of procedure were designed for studies to determine the effectiveness of shields of various types and materials and what influence such factors as distance of projection out from the foundation, types of corners, thickness of the edge, smoothness of the material, and angles have on the frequency of failures of the shields.

In the first method untreated wooden piers 2 by 2 or 4 by 4 inches, depending on the size of the cage, with shields of various types attached on top of them, were placed in unglazed crocks or celluloid cages with plaster of paris bottoms, which were almost filled with topsoil so that 8 to 10 inches of each pier was above the soil. At first these cages were set in trays of water, but the soil in many of them became too wet and they were discarded in favor of 1-gallon tin cans which were watered by hand. Several thousand workers were used for each 100 cubic inches of soil. Shelter tubes were constructed up most of these wooden piers, but because only a few tubes were continued out underneath the shields this method proved to be unsatisfactory for testing certain of the factors involved. The construction of tubes up the wood piers in these cages was not the result of conditions within the cages, because under natural conditions tubes are often built on the surface of untreated wood.

Under the second method the shields were placed directly on top of 1-gallon tin cans. Small outward-projecting lips were beaten in the top edge of the cans so that termites were encouraged to build tubes out underneath the shields. The cans were filled with topsoil to within 2 inches of the top, then strips of moist blotter were placed on top of the soil and around the inside of the cans above the soil. The shield was held firmly on the can by a wooden frame anchored with a bolt which passed through the bottom of the can and the

[1] The writer acknowledges helpful suggestions by T. E. Snyder under whose direction these investigations were made.

shield. A hole 2 inches in diameter in the center of the shield, through which the bolt passed, allowed the soil to be moistened without disturbing the shield (Fig. 1). The cages were infested at the rate of 5000 workers per 100 cubic inches of soil. The soil in all the cages was kept moderately moist.

All the tests described herein were conducted during the period June 1940 to December 1941 in an enclosed laboratory where temperatures usually ranged from 70° to 90° F. and where humidity ranged from 70 to 98 per cent. Individual colonies usually lived 3 or 4 months, but the greater part of tube-building activity occurred within 2 or 3 weeks after the tests were set up. Records were kept on the colony until it became apparent that no further tube building would occur.

In summarizing the results of the tests with wooden piers, all cases in which tubes were built to the top of the piers were considered as tests, and in both methods each tube that ended at or beyond the edge of a shield was considered as an attempt by the termites to build over the edge. In many instances a primary tube extended along the margin of the underside of the shield adjoining the edge, and branches extended out beyond the edge. Each branch was recorded as an independent attempt to cross the edge of the shield. Occasional tubes constructed through the hole in the center of the shield were destroyed and not counted as shield failures.

TESTS OF SHIELDS ON WOODEN PIERS.—Forty-seven cages were used with wooden piers and in 39 of them termites constructed shelter tubes up the piers to impenetrable shields of various types, and in one to a rough wood board which served as a control. The extent of tubing on the piers varied widely. In some cases a single tube was extended up the pier, but in others as much as three sides of the pier were almost completely covered with a profuse mass of tubes. There was no correlation between the extent of tubing on the pier and on the shield. In some instances one or two individual tubes were built up the pier and over the shield, but in others the profuse mass of tubes ended abruptly at the shield. The results of this series of tests are summarized in table 1.

On the 39 piers on which tubes were constructed to impenetrable shields, 23 of the shields, or 59 per cent, had no tubes built on the underside, and underneath 5 of them, or 13 per cent, the tubes were less than 2 inches long and did not reach to the edge of the shield. This gives a combined effectiveness of 72 per cent for the portion of the shield lying directly above the pier and the portion projecting 2 inches from the pier. These results indicate that termites are disinclined to build tubes from piers or walls out underneath metal shields, and that the most important parts of shields are in the portions directly above the pier or wall and the parts projecting 2 inches out rather than in any angle at which the shield is turned downward or in any additional width.

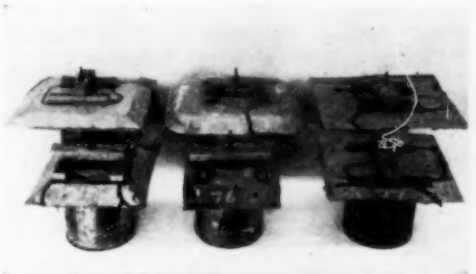

FIG. 1.—Metal termite shields with termite shelter tubes constructed over them. Rear row: Left, standard shield of 26-gauge galvanized iron which projects 2 inches horizontally and 2 additional inches downward at a 45° angle; center, shield of 26-gauge copper-bearing steel which projects 2 inches horizontally and 2 additional inches down at a 45° angle, angles and corners rounded; right, shield of 26-gauge galvanized iron which projects 4 inches horizontally. Front row: Left, shield of 26-gauge galvanized iron which projects 2 inches downward at a 45° angle; center, shield of 26-gauge galvanized iron which projects 2 inches horizontally and 2 additional inches down at a 90° angle; right, shield of 26-gauge galvanized iron which projects 2 inches horizontally.

Of the shields which projected 4 inches from the pier, 3 shields, or 8 per cent of the 39 impenetrable shields tested, had tubes about 3 inches long, but none of them reached the outer edge of the shield. This 8 per cent of effectiveness may possibly be attributed to the additional 2 inches on the projecting portion of the shield, although later investigations would indicate that added distance is unimportant.

Tubes were continued to the edges of 8 shields, or 20 per cent of the impenetrable shields, but the thin edges stopped a high percentage of them. The edges of

shields of 26-gauge galvanized iron which projected 2 inches horizontally from the pier and 2 additional inches downward at an angle of 90° were 100 per cent effective. The edges of shields of like material which projected 1 or 2 inches horizontally and 1 or 2 additional inches downward at a 45° angle stopped 84 per cent of the tubes, and the edges of simple shields which projected 2 inches horizontally with the edges not in contact with wood were 89 per cent effective.

TESTS OF SHIELDS ON TOP OF CAGES.—Shelter tubes were constructed to the outer edge of 41 shields fastened directly on the tops of cages, and no tubes were constructed on 13 additional ones. Most of these 13 instances occurred in a group of tests that were set up at one time, and failure of the termites to build tubes was probably due to faulty technique in handling the colonies. Results of the other 41 tests, which are summarized in table 2 formed by the foundation and the shield.

Table 1.—Results of laboratory tests of termite shields installed on wooden piers. (Shults 26-gauge galvanized iron except where otherwise indicated.)

Type of Shield	Shields			Piers with—		Tubes Stopped before Reaching Edge of Shield	Shelter Tubes to and beyond Edge of Shield		
	Installed	No[1] Results	Failed	Tubes Stopped at Top of Pier	Tubes Built under Shield		Total	Stopped at Edge	Constructed over Edge
	Number	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
2″ hor. and 2″ down at 45° angle (Standard shield)	7	0	0	5	2	4	0	0	0
2″ hor. and 2″ down at 45° angle (Round corners)	5	2	0	1	2	4	16	16	0
2″ hor. and 2″ down at 90° angle	8	0	0	6	2	4	13	13	0
2″ hor. and 2″ down at 45° angle (copper-coated paper)	1	0	1	0	1	0	2	0	2
4″ horizontally	1	0	0	1	0	0	0	0	0
1″ hor. and 1″ down at 45° angle	8	2	2	2	4	3	3	0	3
0″ hor. 2″ down at 45° angle	1	0	0	1	0	0	0	0	0
2″ horizontally	9	0	1	5	4	7	9	8	1
2″ horizontally[2]	1	0	1	0	1	0	2	0	2
2″ horizontally (cast iron)	3	3	0	0	0	0	0	0	0
2″ horizontally (slate)	2	0	0	2	0	0	0	0	0
2″ horizontally (wood 1″ thick)	1	0	1	0	1	0	Profuse mass	0	Profuse mass
Total	47	7	6	23	17	22	45[3]	37	8[3]

[1] No results were obtained because there were no tubes built on the piers.
[2] Edge of shield in contact with wood that was placed on top of the shield so that the deterrent effects of the edge of the shield were nullified.
[3] Not including the profuse mass of tubes on the wooden shield.

In contrast to the meager tubing underneath and over the edges of impenetrable shields, the lower surface and two edges of a shield of rough, 1-inch-thick board were almost covered with a profuse mass of tubes. Although only one wooden shield was used in these tests it appears to indicate that termites will readily build tubes from foundations to the lower surface of rough material, whereas with metal or smooth-surface shields a majority of the tubes either stop at the top of the foundation or are continued in the angle do not represent the total efficiency of shields but show only the frequency of failures of the shields in instances where tubes are actually constructed to the edge. Plywood, glass, and plastic have no practical value as shields but were included for test purposes only.

By comparing data in table 2 on shields of the same material, it will be seen that the width of a shield, within the range tested, is of no importance as a factor influencing its effectiveness. For example, with two shields of 26-gauge galvanized

iron which projected 2 inches horizontally from the outside of the cages, 31 tubes reached the edge, but only 6 per cent of them continued over the edge, whereas with 4 shields which projected 4 inches horizontally, 40 tubes were built to the edge, and 20 per cent of them continued around the edge. Only one of the 2-inch shields failed but all the 4-inch ones were crossed by termites. Furthermore, in numerous cases tubes were continued more than 6 inches downward from the edges of the various types of shields, which further indicates that distance within the range of these tests is unimportant.

Whether the corners of shields were even and smoothly soldered, gently curved, or corrugated were considered as factors which might influence the frequency of shield failures. These tests indicate that the type of corner is not of great importance, for in most cases where the shield failed the tubes were built over the edge some distance from rather than directly in the corners. Outstanding examples of this were two shields which projected 2 inches horizontally and for an additional 2 inches downward at a 45° angle. The corners of these shields were purposely made rough and uneven, but on these shields three tubes were built over the

Table 2.—Results of laboratory tests of termite shields installed on top of cages.

Type of Shield	Material	Shields		Shelter Tubes to and beyond Edge of Shields				
		Tested	Failed	Total	Stopped at Edge		Constructed over Edge	
		Number	*Per cent*	*Number*	*Number*	*Per cent*	*Number*	*Per cent*
2″ hor. and 2″ down at 45° angle (Standard Shield)[1]	26-ga. galv. iron	5	80	47	39	83	8	17
2″ hor. and 2″ down at 45° angle (with poor corners and joints)	26-ga. galv. iron	2	100	22	19	86	3	14
2″ hor. and 2″ down at 45° angle (with beaded edge)	26-ga. galv. iron	1	100	7	5	71	2	29
2″ hor. and 2″ down at 45° angle (with round corners)[1]	26-ga. copper-bearing steel	2	100	33	31	94	2	6
2″ hor. and 2″ down at 45° angle (corrugated corners)	26-ga. copper-bearing steel	3	100	33	30	91	3	9
2″ hor. and 2″ down at 45° angle (slip joint connectors)	26-ga. copper-bearing steel	3	67	30	28	93	2	7
2″ hor. and 2″ down at 90° angle[1]	26-ga. galv. iron	4	25	9	8	89	1	11
4″ horizontally[1]	26-ga. galv. iron	4	100	40	32	80	8	20
2″ down at 45° angle[1]	26-ga. galv. iron	3	67	28	24	86	4	14
2″ horizontally[1]	26-ga. galv. iron	2	50	31	29	94	2	6
2″ horizontally	26-ga. galv. iron (rusty)	2	100	11	3	27	8	73
4″ horizontally	plywood 1/53″ thick	3	100	23	13	57	10	43
4″ horizontally	plywood 1/16″ thick	3	100	7	1	14	6	86
4″ horizontally	glass 1/16″ thick	2	100	19	12	63	7	37
4″ horizontally	glass 1/8″ thick	1	100	18	16	89	2	11
2″ horizontally	plastic 1/50″ thick	1	100	5	1	20	4	80

[1] Type illustrated in figure 1.

edge away from the corners, and no tube crossed at the inferior corners. Indications are that corrugated corners are equally as effective as the smooth, round corners, and that the connectors used to join some of the shields did not aid termites in crossing the edge of the shield. No tubes were constructed through the joint connectors used in these tests, and of five tubes that reached the edge of a shield along a joint only one continued over the edge. These data indicate that termites do not necessarily seek inferior corners or rough surfaces on which to build tubes but may cross the shield at any point where the edge is reached. Good corners and joints, however, are to be encouraged, for termites may use rough surfaces along the edge of a shield should they chance on them.

Thin edges apparently reduce the frequency of shield failures, but do not entirely prevent tube construction. A higher percentage of tubes crossed the edge of a shield of 26-gauge galvanized iron with the edge beaded than of shields of the same material with unbeaded edges, and plywood boards 1/16 inch thick were crossed more frequently than were those with edges approximately the thickness of 26-gauge galvanized iron. Four out of five tubes were constructed over the edge of plastic only 0.02 inch thick, but the fact that a high percentage of tubes stopped at the edge of shields of 26-gauge galvanized iron, which is slightly less than 0.02 inch thick, indicates that very thin edges acted as deterrents.

Tube construction on the under surface of smooth material usually progressed somewhat more slowly than underneath rough surfaces. This was probably due to the fact that the material of which the tubes were made did not readily adhere to the smooth surfaces. Apparently the edges of smooth material were crossed with difficulty, for usually the tubes rebranched at the edge of glass and plastic shields until a supporting ledge of earth was made. From this ledge a tube was constructed over the edge. There was somewhat less branching at the edge of metal shields, and in most cases with thin plywood a single tube continued over the edge. A comparison of horizontal shields of the same thickness, regardless of width, shows that 73 per cent of the tubes on rusty metal crossed over the edge, 43 per cent crossed the edge of plywood, and 14 per cent were built over the edge of new 26-gauge galvanized iron. This variation in percentage of crossings is apparently due to the variation in the smoothness of the edge of these materials. Eighty per cent of all tubes on a thin, smooth plastic shield were continued over the edge, but this single case was probably an exception.

Bending a shield downward at a 45° angle apparently has no appreciable effect on the frequency of tube construction over the edge. Seventeen per cent of the tubes crossed the edge of well-constructed shields of 26-gauge galvanized iron which projected 2 inches horizontally and for an additional 2 inches downward at an angle of 45°, as compared with 20 per cent that crossed the edge of shields of the same material that projected 4 inches horizontally with no downward projection. In the case of metal shields with no horizontal projection but with 2-inch projections bent downward at a 45° angle at the wall of the cage, 14 per cent of the tubes crossed the edge of the shield, whereas only 6 per cent of the tubes crossed the edge of shields of the same material that projected 2 inches horizontally only.

A downward angle of 90° considerably increased the efficiency of metal shields. Of 9 tubes constructed to the edge of shields of 26-gauge galvanized iron which projected 2 inches horizontally and for an additional 2 inches downward at a 90° angle, only 1 tube was continued over the edge. This single case, however, is sufficient to demonstrate the ability of termites to build tubes around shields of this type. In experiments not described herein but which served to test this type of shield, 38 tubes reached below the edge of the shield but none were constructed around the edge. Thus of a total of 47 tubes only one of them was built around the edge of this type shield. A possible explanation for the higher efficiency of the 90°-angle type may be that less of a supporting ledge of earth from which to build over the edge is afforded by tubes constructed to or slightly below the edge of a perpendicular surface than is made by such tubes on either horizontal or 45° surfaces.

Certain of the factors studied, particularly smooth surfaces, thin edges, and a 90°-angle downward, influenced the value of the shield, but no combination of

them was sufficient to entirely prevent tube construction. Furthermore, no combination of these factors will explain why some tubes continued over the edge of an individual shield while others did not. Along similar edges, it appears that an element of chance coupled with the vigor and persistence of the termite colony determines to some extent whether tubes continue over a shield or stop at its edge.

DISCUSSION.—*Results* of these laboratory tests indicate that in a high percentage of cases properly made and installed metal shields will prevent the upward progress of termite tubes through or over foundations to the woodwork of buildings, but shields should be used only as a supplement to good construction. The use of shields, therefore, should be accepted only as an additional precaution where it is desired to use very possible means to avoid an infestation.

The use of shields does not guarantee complete control of termites even in cases where they are used in connection with good construction, for, as demonstrated by these laboratory tests, termites are capable of building their shelter tubes over any type of shield included in these tests (Fig. 1). Therefore periodic inspections for the presence of such tubes are necessary. Where crossings occur, however, the shield will have served the useful purpose of forcing the termites into the open, thereby avoiding hidden attack through unit masonry foundations on which shields are most useful. If termites succeed in building tubes around the shield, the infestation may be controlled by repeatedly breaking the tubes from the shield until activity ceases.

Since in over 70 per cent of the cases termites did not build tubes to the edges of shields that projected 2 inches from the piers, and because neither the 45° angle downward nor added width greatly influenced the effectiveness of shields, it would appear that a simple flat or horizontal shield of 26-gauge galvanized iron which projects 2 inches from the foundation would afford as much protection against the eastern subterranean termite as do the standard 45° types previously recommended by the Bureau of Entomology and Plant Quarantine.

The projections of shields used under service conditions, however, should be bent downward sufficiently to shed water and to break contact between the edge of the shield and any woodwork of the building, for if the edge of the shield were left in contact with wood the deterrent effects of the thin, smooth edge, which are important features in preventing termites from building tubes around a shield, would be nullified. Since bending can be accomplished after installation, the horizontal type shield has the advantage of being easier to construct and install than the 45°-angle type.

In these tests shields with projections bent downward at a 90° angle were more effective than any of the other types. For service conditions, however, this type would be more difficult to construct and install, and these also are the outstanding disadvantages of the standard 45°-angle types.

The greatest difficulty in the use of metal shields is to insure that they are properly installed. Too often shields are used only on the parts of the foundation where they can be installed easily, while the points where the great majority of termite infestations occur, such as back of porches, steps, and terraces, are left unprotected. This situation is more fully discussed in United States Department of Agriculture Farmers' Bulletin No. 1911, in which detailed instructions are given for using metal barriers at the more vulnerable points. Or a simpler, cheaper method of insulation is to separate all steps, porches, and terraces that have contact with the soil by a space of at least 1.5 inches from the main building. Unless protection is provided at these more vulnerable points the use of shields on other parts of the foundation is largely a waste of money and materials.

SUMMARY.—Laboratory tests were made of various types of termite shields to determine what form or shape would be most effective in preventing subterranean termites from building tubes up to the woodwork of a building, and to determine the fundamental principles that influence their effectiveness.

Sample shields were fastened on top of piers or cans, and the soil in which the piers were set or which was put in the cans was artificially infested with termites.

Every type of shield tested was crossed at least once by a termite tube. The form proving most effective was that having a projection of 2 inches horizontally and an

additional 2 inches downward at a 90° angle, but this type is difficult to construct and install properly.

Smoothness of the surface of material and thin edges aided in stopping tube building, but if thin, smooth edges are in contact with wood or other objects their deterrent effects are nullified.

Since no type of shield yet devised has been found entirely effective it is necessary to make occasional inspections of all shields that are installed.

A simple shield of 26-gauge galvanized iron which projects at least 2 inches from the foundation, and which is bent downward sufficiently to break contact between the edge of the shield and the woodwork of the building affords as much protection as do the standard 45°-angle types and is more economical to construct and install.

Improper or incomplete shield installations are a waste of money and materials and give the home owner a false sense of security.—2-1-43.

The Control of *Limonius agonus* (Say) on Shade-Grown Tobacco in Connecticut, 1937–42

A. W. MORRILL, JR., *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*[1]

Experiments were begun in 1937 on the control of the eastern field wireworm, *Limonius agonus* (Say), attacking shade-grown tobacco in Connecticut. This wireworm, formerly reported as *Limonius ectypus* (Say), has become increasingly prevalent on both potatoes and tobacco. It may be found in many fields at any season of the year. Even in midwinter individuals have been taken from the frozen soil and brought into the laboratory, where they resumed activity upon being thawed.

FIG. 1.—Young tobacco plant showing feeding by *Limonius agonus* and worm *in situ*.

Usually, however, the larvae come up into the topsoil in largest numbers about the middle of April. Growers who plant a cover crop of rye, which remains alive over the winter, have reported that the wireworms apparently feed on the rye at this time instead of attacking the tobacco so severely when it is set, some weeks later. In fields planted to oats, which do not live over winter, the damage to newly set tobacco plants is much more severe. Comparative strips of cover crops, which seemed to demonstrate this phenomenon, have been observed by the writer over several seasons.

Where the cover crop or other factors do not reduce their activity, the wireworms remain in the topsoil more or less constantly until the end of June, when drier and hotter conditions in the upper soil drive them periodically to lower depths. In the meantime they have gnawed the cambium or eaten burrows into the pith of the roots of the small and succulent, newly transplanted tobacco plants (Fig. 1).

Although the older plants can and do withstand such attack later in the season without noticeable damage to growth or quality, the attack of even one wireworm is sufficient to cause a young plant to wilt, become stunted, or, as is more usual, die. As plants are set about 13,200 to the acre, or 1 to every 3.3 square feet, a population of even 1 wire worm per cubic foot of earth is dangerously high. A population of this density may cause the restocking of

[1] In cooperation with D. S. Lacroix, assistant entomologist, Connecticut Agricultural Experiment Station. The assistance of Dr. R. L. Beard, assistant entomologist of the same station, in making the soil examination in 1942 is also gratefully acknowledged.

fields many times in succession (Morrill & Lacroix 1941), an operation which is costly in labor and in its effect on the rate at which the tobacco reaches maturity.

METHODS AND MATERIALS.—In 1937 tests were conducted in two fields which had already suffered severe damage from wireworms, causing a loss of the first setting of plants. Because tobacco is set as early as a trap crop would grow in Connecticut, the use of trap crops followed by fumigation was deemed impracticable. Such a practice would have delayed maturation of the crop by some weeks, which would be undesirable from several standpoints of harvesting, curing, and quality of leaf. Two materials were therefore tested—naphthalene and dichloroethyl ether—each of which had given good results in other sections of the country and which could be used at setting time (Lane 1937; Campbell & Stone 1937).

The naphthalene was sprinkled along the bottom and slice of 9-inch-deep furrows, the furrows being plowed every 9 inches rather than the usual 12 inches. The field was then triple-harrowed after the plowing and the plants set at once. The dichloroethyl ether was applied in the water placed around the young plants by the setting machine, at the rate of about 100 cc. per gallon of water, 0.3 pint of the mixture being poured into the furrow with the setting of each plant.

In 1938 similar tests were conducted. The plots used in these tests were 0.25 acre in area and were laid out in duplicate, but not at random.

In 1939 the plots were 0.05 acre in area and in 1940, 1941, and 1942 they contained 0.025 acre. During these seasons the plots were replicated 12 times and were arranged in randomized blocks. In 1939 only napthalene was tested, application being made on May 2, a month prior to setting, to test the feasibility of treating the soil at a time when soil temperatures were too low for setting and when treatment would thus interfere less with the normal cultural routine. The methods used were those previously described for 1937.

Two rates of application of naphthalene were tested in 1940—800 and 1000 pounds per acre. The applications were made on June 13, when a cover crop of green rye about 12 inches high and winter-killed oats was plowed into the soil. Thorough aeration of the soil by double plowing prior to the application of the naphthalene was tested in 1941 and dichloroethyl ether and p-aminoacetanilide, applied in the setting water, were included in the tests.

In 1941, also, a new series of plots, arranged in randomized blocks, was treated in the fall with deep plowing and with carbon disulfide, applied after harvest by means of a weed-killer-type soil injector (Fig. 2). The methods used were those previously recommended for use in other regions (Hawkins 1936; Lane & Gibson 1932; Lane 1941). One ounce of carbon disulfide was applied every 18 linear inches in each direction, the material being injected to a depth of 4 inches. These plots were reexamined in the spring of 1942 for residual effects of the treatments. Untreated check plots were provided in all cases.

FIG. 2.—Applying carbon disulfide to a tobacco field, in the fall after harvest, for control of wireworms.

To determine the effectiveness of the treatments, soil from unit areas was sifted to a depth of 1 foot and the population of wireworms counted. In 1937 and 1938, hand-operated sifters were used and subsequently a power-driven sifter was employed. This has been previously described (Morrill 1939). Until the fall of 1941 the sampling units taken were 1 square foot in surface area and from 3 to 6 were taken per plot. In the fall of 1941 and the spring of 1942 the sampling units were reduced to one-fourth square foot in size but were increased to 12 in number. Soil units for sampling were located within the plots by means of random numbers but none was taken within 6 feet of the borders of any

plot. Screens of 4-mesh hardware cloth were used in sifting, as it had been proved that finer meshes clogged badly, except when the soil was too dry for wireworms to be present. These 4-mesh screens divided the soil into sufficiently fine particles so that, although the wireworms dropped through, they were readily detected. Larvae as small as three-eighths inch in length were recovered.

RESULTS.—The preliminary results obtained with the tests conducted during 1937 and 1938 did not warrant the drawing of any conclusions. In later experiments, in which 12 replicates were made, the reduction in wireworm infestation was significantly greater in the plots treated with napthalene or with dichloroethyl ether than in those not treated, but the reductions obtained were not sufficient to be of much practical value to the grower.

In 1939 the test consisted of a comparison of the effect of no treatment with that of naphthalene applied at the rate of 800 pounds per acre on May 2, nearly 1 month before setting time. The soil temperature was 48° F. at a depth of 12 inches and remained below 70° until the third week in June. There was an average of 1.6 and 1.9 wireworms per square foot in the 12 treated and in the 12 check plots, respectively, at the time of the application of naphthalene. Tobacco plants were set in the plots on June 1, when there was an average of 1.7 wireworms in the check plots and 1.6 in the treated plots. Samples taken at weekly intervals from between the rows of tobacco showed that no appreciable control of wireworms was exerted until the middle of June. In samples taken on June 21, however, there were 1.8 wireworms per square foot in the check plots and 50 per cent less (0.9 wireworm per square foot) in the plots treated with naphthalene. An analysis of variance demonstrated that this reduction is of mathematical significance. Less restocking was necessary in the treated plots than in the check plots but the value was within the limits of experimental error. The experiment gives evidence that during cold weather, lasting as long as 6 weeks, naphthalene will remain in the soil and become effective when the temperature rises. Under these conditions, however, the material is not sufficiently effective to constitute satisfactory control.

Table 1.—Effect of soil temperature and applications of various insecticides on the population of the eastern field wireworm. Buckland, Conn., 1941.

Date	Soil Temperature (° F.) at 12-Inch Depth	Living Wireworms Found per Square Foot with Treatment as Indicated					
		None (Check)	Naphthalene	p-Aminoacetanilide	Dichloroethyl Ether	Carbon Disulfide	Deep Plowing
Before application:							
June 3	64	0.9	0.9	0.6	0.9		
After application:							
June 17	68	1.7	1.1	1.3	1.1		
July 9	66	1.8	1.1	1.1	0.9		
Before application:							
September 12	64	1.8				1.7	1.8
After application:							
September 18, 1941	68	1.2				0.2	
April 20, 1942	43	0.8				0	0.6

In 1940, following the application of the naphthalene on June 13, the plots were set with tobacco plants on June 15. The numbers of plants killed by wireworms were 79, 51, and 52 for the check, 800-pound, and 1000-pound treatments, respectively.

Results of the tests made in 1941 are given in table 3. Naphthalene again caused a reduction of the population which was mathematically significant but insufficient for practical value to the grower. The effect of the dichloroethyl ether was sufficient to suggest the desirability of testing the material further under different conditions of application, while the p-aminoacetanilide, as used, was apparently without effect.

As the investigations were terminated after only one season of deep late-fall

plowing, the effectiveness of this method of control cannot be gaged. The carbon disulfide, however, proved highly effective, an immediate reduction of 87 per cent occurring in September and no wireworms being found at setting time the following spring. The method cannot be used during the growing season while the tobacco plants are actually being attacked, because it has been found that the dosages necessary to kill the worms would kill the plants as well. However, the presence of wireworms in a field is usually known to the grower some years before the population becomes dangerous and before the climatic or setting conditions combine to produce an attack destroying many acres, or even any considerable sections of the field. In addition, wireworm populations tend to remain in one locale, frequently occurring in any density only in a few bents or sections of a field. The carbon disulfide can be used in a threatened field immediately upon the completion of harvest, when the soil is still warm and the wireworms are still near the surface. Its action at this time is rapid and thorough and apparently very effective in destroying the greater part of the wireworm population.

SUMMARY.—Experiments on the control of wireworms attacking tobacco in Connecticut were initiated in 1937 and continued to the spring of 1942. For the first 2 years results were inconclusive. Thereafter plots were replicated 12 times and arranged in randomized blocks. Dichloroethyl ether and naphthalene were tested, and in the fall of 1941 a new series was started in which the values of deep plowing and of the application of carbon disulfide immediately following harvest were tested. Populations of wireworms were determined by sifting soil samples through 4-mesh hardware-cloth screens. From 3 to 6 soil samples 1 foot deep and 1 square foot in surface area were taken until the fall of 1941, when sampling units were reduced to one-fourth square foot and the number taken was doubled.

Although the reduction in wireworm infestation was significantly greater in the plots treated with naphthalene and with dichloroethyl ether than in those not treated, the reductions obtained were not sufficient to be of much practical value to the grower. That obtained by the use of dichloroethyl ether was sufficient to suggest the desirability of testing the material further under different conditions of application. The naphthalene was tested under sufficiently varying conditions of climate and application so that it would seem clear that, except under unusual conditions of high soil temperatures at setting time, the material is not satisfactory as a control method in this region. The p-aminoacetanilide, as used, was apparently without effect. The reductions of wireworm populations, both immediately following the treatment with carbon disulfide and at setting time the following spring, were highly significant. The use of this material in the fall after harvest in fields threatened with wireworm attack is apparently very effective in destroying the greater part of the wireworm population.—1-12-43.

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Penetrating Sprays to Control the Mountain Pine Beetle[1]

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For many years outbreaks of the mountain pine beetle, *Dendroctonus monticolae* Hopk., in lodgepole pine have been controlled by treating the infested trees in one of the following ways: (1) Felling and peeling, (2) felling, decking, and burning, or (3) burning standing. These methods were effective but possessed the following disadvantages: (1) High cost, (2) danger of fire, and (3) the necessity because of that danger, of confining control work to periods when weather, transport, and working conditions are adverse. These objections indicated the need for a method of treatment to supplement or supplant present methods, which would not involve the use of fire, could be carried on under favorable working conditions, and would be reasonable in cost. Accordingly, penetrating oil sprays were tried, as previous work with them had indicated that they might be effective. The studies were carried on during the years 1934 to 1938.

The sprays that had given the best results against the western pine beetle, *Dendroctonus breviconis* Lec., in ponderosa pine in California (1938), as well as other chemicals, were tested at various places in Montana, Idaho, and Wyoming. Only trees or logs containing abundant brood were used. Such material is generally found in the larger trees having thicker-than-average bark, and as effectiveness of the oil sprays decreases slightly with increased bark thickness, the data may be considered as giving a conservative estimate of the average beetle mortality that could be obtained on a control project. Enough logs or trees of each host were treated on various sites to indicate the general effectiveness of the method. Thorough coverage by the spray was assured by treating until the liquid on the bark surface glistened and began to flow, this condition being reached when approximately 90 square feet of bark surface has been treated per gallon of spray. To be certain that the mortality obtained was the result of treatment, data from sprayed portions of the trees or logs were compared with those from untreated parts of the same tree and from nearby unsprayed trees. The spray was applied by means of 3-gallon-capacity pressure sprayers of the garden type.

The various sprays tested, together with their cost and relative effectiveness, are shown in table 1.

The first spray mixture had a low material cost and gave excellent control, but considerable labor was involved in putting and keeping the naphthalene flakes in solution. Cost of the chemicals used is based on past purchase prices and quotations, subsequent changes in which would influence the choice of spray to be used.

The third and fourth sprays gave consistent results in experimental tests and practical demonstrations on control projects. The third was slower in action but gave excellent results when used on the experimental control project conducted on the Wasatch National Forest in 1940.

From these studies it was evident that consistently effective control by sprays can be expected under green or wet bark, which is often found at the base of infested trees. In wet areas survival of a small percentage of the insects in the treated tree may be expected.

In the search for a carrier of the lethal materials, various petroleum derivatives and water, both with and without wetting agents, were tested. Only the oils gave acceptable results, and as these showed little difference in their effectiveness, choice was reduced to the factor of cost, which placed diesel oil of 27+° Baumé gravity in the preferred position. The addition of wetting agents did not give consistently better results. Only a few tests have been made with water-base or emulsion sprays, the possibilities of a large field being left for future investigations.

Further tests may show that the ratio of the more expensive lethal agents to oil can be reduced sufficiently to make their use more economical and still give satisfactory control.

As whitebark pine, which is an accepted host of the mountain pine beetle, often grows in association with or adjacent to lodgepole pine stands, it is necessary that a method of control be equally effective

[1] F. C. Craighead and J. C. Evenden assisted in planning the work.

Table 1.—Sprays tested against the mountain pine beetle in lodgepole pine, together with their cost and effectiveness.[5]

GALLONS OF OIL		LETHAL AGENT	NUMBER OF SAMPLES	COST OF SPRAY PER GALLON[1]
		Formulas giving over 95 per cent brood reduction		
Light stove	3	Naphthalene flakes[2]		
Heavy stove	1	1 lb. per gal.[3]	81	$0.16½
or				
Diesel	4	Napthalene flakes		
		0.75 lb. per gal.	32	.15
		Orthene 1 gal.[3,4,5]	106	.22
		Naphthalene flakes 3 lb. and *Orthene* 1 gal.[3]	127	.25½
		Orthene saturated with naphthalene flakes at rate of 3.6 lb. per gal.—1 gal. (saturated solution at 60° F.)	10	.26
Light stove	6	Naphthalene flakes 3 lb.		
Heavy stove	2	*Orthene* 1 gal.	30	.19
or				
Diesel	8			
Diesel	9	*Orthene* saturated with naphthalene flakes at rate of 3 lb. per gal.—1 gal. (saturated solution at 50° F.)		
		Wetting agent 1 per cent by weight	6	.21½
Diesel	8	Dichlorethyl ether—1 gal.	7	.29
		Orthene 1 gal. and naphthalene flakes 1.5 lb., wetting agent 2 per cent by weight	10	.30½
Diesel	6	*Orthene* saturated with naphthalene flakes at rate of 3 lb. per gal.—1 gal. (saturated solution at 50° F.)	5	.19½
Diesel	4	Dichlorethyl ether 1 gal.	10	.44
Diesel	3 parts by weight	Orthonitrodiphenol 1 part by weight	6	.60
Diesel	2	Ethylene dichloride 1 gal.	10	.42
Kerosene	3	*Orthene* 1 gal.	5	.36
Heavy stove	58	Toluene 20 gal., diphenol 20 gal., pentachlorphenol 2 per cent by weight	10	.76
Orthene			5	.70
		Formulas giving between 90 and 95 per cent brood reduction		
Diesel	9	*Orthene* saturated with naphthalene flakes at rate of 3 lb. per gal.—1 gal. (saturated solution at 50° F.)	6	.16½
Diesel	8	*Orthene* 1 gal.	10	.17
Diesel	5	Xylene saturated with naphthalene flakes at rate of 3 lb. per gal.—1 gal. (saturated solution at 50° F.)	7	.20½
Stoddard solvent	3	*Orthene* 1 gal.	10	.40
Heavy stove 70 per cent by weight		Toluene 15 per cent, diphenol 15 per cent by weight	10	.53
Heavy stove 60 per cent by weight		Toluene 20 per cent, diphenol 20 per cent by weight	10	.70

[1] Based on following costs: Orthodichlorobenzene $0.70 per gallon, naphthalene flakes $0.08 per pound, and oil $0.10 per gallon.
[2] Heating necessary to dissolve and keep naphthalene in solution at near-freezing temperatures.
[3] Tested in 2 or more years. All other formulas were tested in 1 year.
[4] Orthodichlorobenzene.
[5] An additional test involving 4 gallons of light stove oil to 1 gallon of *Orthene* is included in the total of this experiment.

in both tree species if the best results are to be obtained. Because of this requirement, tests in whitebark pine were instituted in 1939 using the sprays which had proved most effective in lodgepole pine. As whitebark pine grows at a higher elevation and consequently in a cooler environment than lodgepole pine, the mountain pine beetle often requires 2 years to complete its life cycle in the former host. Therefore tests conducted at any time would be against brood in various stages of development, from eggs in trees recently attacked to new adults in others attacked 1 or 2 years previously. In the treatment of newly attacked trees containing eggs and small larvae, it was expected that the relatively green bark would resist the penetrant; however, from the tests conducted it would seem that

fair success can be obtained from such treatments (table 2).

There was little difference between the results obtained in the two years of tests, except for the first formula, which in 1939 gave unsatisfactory control against the early stages of brood development but in 1940 gave excellent control against the same brood stages. This difference is believed to have been due to the fact that in 1940 the period between the time of treatment and the subsequent examination was 3 weeks longer. This longer exposure to the effect of the spray seems to have caused the higher mortality. The tests indicate that a satisfactory effectiveness can be obtained with penetrating sprays against the mountain pine beetle in whitebark pine whether in the advanced or early stages of brood development.

It is difficult to compare costs of bark beetle control on different projects because of variations in size and concentration of infested trees and in site conditions, all of which influence the cost of transportation, labor, and supervision. A project employing penetrating sprays conducted with the cooperation of the United States Forest Service on the Wasatch National Forest during the 1940 season, in which 1235 trees were treated, revealed a cost of $2.71 per tree. Although this figure is but slightly below the average cost per treated trees of the other methods used during the same season, it is believed that as experience is gained in the administration of this method the above cost can be considerably reduced.

SUMMARY.—Tests conducted against the mountain pine beetle in lodgepole and whitebark pine reveal that certain penetrating sprays are highly toxic to the broods beneath the bark. Sprays of diesel oil and orthodichlorobenzene combined low cost and control effectiveness to the greatest degree of any formula tested. Control by penetrating sprays has the advantage of giving most satisfactory results during the more favorable working conditions of late spring when present methods can not be used because of the hazard involved in the use of fire. The higher costs of materials used in penetrating sprays are expected to be largely offset by lower operation costs due to the better working conditions and a longer period during which spraying can be carried on. —1-11-43.

Table 2.—Sprays tested against the mountain pine beetle in whitebark pine, together with their cost and effectiveness.

GALLONS OF OIL	LETHAL AGENT	NUMBER OF SAMPLES	COST OF SPRAY PER GALLON
	Formulas giving over 95 per cent brood reduction for		
	(A) Brood in advanced stages of development (mature or nearly mature larvae, pupae, and new adults)		
Diesel 4	*Orthene*[1] 1 gal. naphthalene flakes 3 lb.	22[2]	80.25½
	Orthene saturated with naphthalene flakes at rate of 3 lb. per gal. (saturated solution at 50° F.) 1 gal.	7	.26½
Diesel 3	*Orthene* saturated with naphthalene flakes at rate of 3 lb. per gal. (saturated solution at 50° F.) 1 gal.	7	.30½
	(B) Brood in early stages of development (eggs and tiny larvae)		
Diesel 4	*Orthene* saturated with naphthalene flakes at rate of 3 lb. per gal. (saturated solution at 50° F.) 1 gal.	6	.26½
Diesel 3	*Orthene* saturated with naphthalene flakes at rate of 3 lb. per gal. saturated solution at 50° F.)	7	.30½
	(Formula giving between 80 and 85 per cent brood reduction for		
	(B) Brood in early stages of development (eggs and tiny larvae)		
Diesel 4	*Orthene* 1 gal. naphthalene flakes 3 lb.	5[2]	.26½

[1] Orthodichlorobenzene.
[2] Tested in 1939, others in 1940.

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Intensity of Attacks by *Scolytus multistriatus* at Distances from Dispersion and Convergence Points[1]

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The dispersion of the smaller European elm bark beetle, *Scolytus multistriatus* (Marsham), the principal carrier of *Ceratostomella ulmi* Buisman, the organism that causes the Dutch elm disease, is manifested by two activities. One of these is crotch feeding, evidenced by twig crotch injuries; and the other is breeding, evidenced by maternal or brood galleries.

Healthy trees are often inoculated by crotch feeding, as described by May & Collins (1938), and reservoirs of contaminated beetles are created through the breeding activity, Collins *et al.* (1940). A knowledge of the distances these beetles will disperse during these activities is important in the development of practices for the control of the Dutch elm disease.

Some studies by Collins (1938) and Wallace (1940) and in 1942 by Wadley & Wolfenbarger[4] have shown that crotch injuries decreased as the distance increased from the point where beetles were emerging. Wallace (1940) also presented some data showing that the percentage of crotch injuries decreased rapidly as the distance increased from logs where beetles were converging for breeding. Published data are lacking, however, on the relative decrease of beetle galleries with the increase in distance from the beetle source. Some observations by Whitten[5] in 1938 indicated that *Scolytus multistriatus* dispersed 2 miles from en elm-free area for breeding in susceptible wood.

The present paper gives the results of experiments conducted in 1940 and 1941. The results show (1) percentages of twig crotches injured around a dispersion point (source of emerging beetles), (2) percentages of twig crotches injured around trap trees (where beetles came for breeding), termed "convergence points," (3) percentages of twig crotches injured about a point where beetles emerged from brood logs and where trap trees suitable for breeding were immediately available, and (4) numbers of brood galleries in trap trees at distances from the dispersion point.

Experimental Procedures.—Rural areas were selected for experimentation, where elm trees in moderate density were growing along fence rows, stream beds, and roadsides. The area and the trees in it were examined for breeding material and sources of beetles other than those in the experimental materials, and none were found. Sites for the convergence and dispersion points were chosen among stands of small elm saplings 1 to 4 inches in diameter at 6 inches above soil level. Equal numbers of convergence points were chosen in easterly and westerly directions from the dispersion point. Equal distances in both directions from the dispersion point to the convergence points could not be arranged, as it was necessary to locate the convergence points on suitable sites. The same sites, saplings, and distances were used in 1941 as in 1940, except as indicated otherwise. Two additional and more distant convergence points were established in 1941, however, in each of the two directions, but no crotch-injury data were obtained at these points.

Logs infested with *Scolytus multistriatus* were located at the dispersion point, and two recently cut elm trees, or equivalent tree parts, ranging between 5 and 7 inches, d.b.h., were placed at each convergence point to attract beetles. The total bark areas in these traps ranged from 48.1 to 152.0 square feet.

Emergence of beetles at the dispersion point totaled 10,024 in 1940 and 51,145 in 1941. Most of this emergence occurred during August at the time the trap trees were exposed to beetle attack. After 6 weeks' exposure, the trap trees were measured for area, stripped of bark, and examined for galleries of the elm bark beetle. Sample trees around the dispersion and the convergence points selected for uniformity in size, distribution, and posses-

[1] Presented at the Program of the Eastern Branch, New York, November, 1942.

[2] Mr. Jones died February 22, 1941.

[3] This experiment was carried out under the direction of the Forest Insect Laboratory of the Bureau of Entomology and Plant Quarantine located at Morristown, N. J.

Thanks are due R. J. Kowal, W. C. Baker, C. L. Griswold, and A. E. Lants for assistance in collecting the field data.

[4] Wadley, F. M., and D. O. Wolfenbarger, 1942. Regression of insect density on distance from centers of dispersion. (Unpublished manuscript.)

[5] Whitten, R. R. (1938). Unpublished laboratory notes. Morristown, N. J.

Table 1.—Twig-crotch injuries near the point of dispersal of smaller European elm bark beetle in tests at Morristown, N. J.

Distance from Dispersion Point (Feet)	1940		1941		Both Years	
	Total Crotches Examined	Per Cent Injured	Total Crotches Examined	Per Cent Injured	Number of Trees Examined	Number of Trees in Zone
0– 25	1,475	39.3	1,382	36.4	8	52
25.1– 50	2,667	1.9	2,897	15.7	12	110
50.1– 75	2,770	1.9	2,844	2.3	12	208
75.1–100	1,766	.1	2,901	3.3	8	293
100.1–125	—	—	3,743	.2	11	244
125.1–150	—	—	1,377	0	9	129

sion of 100 or more suitable crotches, were examined for injured twig crotches.

In determining the distances between the dispersion points or convergence points and standing trees, the measurements were made to the trunk of the tree. All sampled parts of trees were within the measured distance. In addition to the data on twig-crotch injury around the dispersion and the convergence points, counts were made of the total number of elm trees over 1 inch in diameter, 6 inches above soil level, for each sector.

Crotch Injuries and Distance from Dispersion Point.—A study of the data on the relation of crotch injuries to the dispersion point showed no significant directional effect, therefore the results are presented on the basis of distance only. The number of twig-crotch injuries decreased rapidly as distance from the dispersion point increased. The data are summarized in table 1.

The most important differences are noted between the distance classes. There are slight differences between years, however, which may be attributed, in part, to the fact that there were 5 times as many beetles at the source in 1941 as in 1940.

The data correspond rather closely with those found by Wallace (1940), but show fewer injuries at the points more distant from the source when compared with those obtained by Wadley & Wolfenbarger in 1942. This difference may be attributed in part to the smaller number of beetles at the source point in the present experiments and possibly in part to the smaller size of the trees examined.

Crotch Injuries as Related to Convergence Points.—The relative numbers of twig-crotch injuries about four convergence points are shown in summary form for 1940 and 1941 in table 2. Twenty trees were examined, all within 50 feet of the trap trees, at each point each year.

An irregular decrease in the estimated percentage of beetles making wounds as the distance from the dispersion point in-

Table 2.—Distances from dispersion to convergence points, estimated number of beetles infesting trap trees, estimated percentages of beetles making twig-crotch wounds, and percentages of crotches injured in sample trees within 50 feet of the convergence traps set up for the smaller European elm bark beetle, Morristown, N. J.

Distance from Dispersion Point (Feet)	Number of Beetles Breeding[1]		Per Cent of Beetles Making Wounds[1]		Per Cent of Crotch Injuries Observed	
	1940	1941	1940	1941	1940	1941
278	1974	4606	14.7	28.1	0.29[2]	1.01[3]
310	686	1828	34.4	7.0	.30	.13
670	818	2550	1.5	.5	.03	.02
844	1446	2214	1.3	1.6	.02	.05

[1] Estimates were made as follows: Total number of brood galleries in trap trees multiplied by 2 (which allows a pair of beetles per gallery) gives the estimated number of beetles coming for breeding. The average number of twig-crotch injuries per tree examined was multiplied by the total number of trees within 50 feet to give the total estimated injuries. The estimated total injuries divided by the estimated total beetles gives the estimated portion of beetles making twig-crotch wounds.

[2] Additional data taken at this point, in 1940 only, showed that the percentage of crotches injured was 0.02 in the 50.1–75.0-foot zone.

[3] Some beetle development and emergence from trap trees occurred at this point and caused part of these injuries of 1941.

creased, is shown by the data. Decreases of observed crotch injuries are also apparent. The crotch injuries appear more closely related to the distances from the dispersion point than to the estimated number of beetles engaged in the breeding activity. It is difficult to account for fluctuations in injury at the low levels of crotch injuries which are reached at considerable distances from dispersion points.

Some crotch injuries, but insignificantly small amounts, however, were found in trees nearest the trap piles compared with more distant trees. For example, a regression study was made of the injuries at the 278-foot point for 1940. The results showed that percentages of 1.0 and 0.5 could be expected at 6 and 25 feet from the trap trees, respectively.

CROTCH INJURIES ABOUT ADJACENT DISPERSAL AND CONVERGENCE POINTS.—An area having a growth of elm saplings and not influenced by mature elm trees closer than 1000 feet was selected for the experiment in which elm logs with a beetle infestation ready for emergence and recently cut elm trees for traps, which beetles soon attacked, were simultaneously located at one point. A summary of the results of this experiment is presented in table 3.

The data show that the injured crotches were concentrated near the combined dispersal-convergence point. The concentration of injuries about this point is similar to that about the dispersion point reported above. In view of the scarcity of injuries near the convergence points, in other tests, these results suggest that beetles attack twig crotches near the dispersion point regardless of the immediate proximity of breeding material. Further evidence of this relationship is seen in the comparison of the numbers of emergence holes in the source logs with the number of galleries in the trap logs. The total emergence holes numbered 3185 and the number of beetle galieries in the trap trees was 1612. If each gallery represents 2 beetles, there were 3224 beetles trapped, which is 39 more beetles trapped than were represented by the emergence-hole data.

Table 3.—Percentages of crotches injured by the smaller European elm bark beetle about a combined dispersion-convergence point.

DISTANCES FROM POINT (FEET)	TREES IN ZONES (NUMBER)	TREES EXAMINED (NUMBER)	CROTCHES EXAMINED (NUMBER)	CROTCHES INJURED (PER CENT)
0– 50	88	20	6595	15.5
50.1–100	143	20	6374	1.1
100.1–150	138	20	9348	0.2

BROOD GALLERIES AND DISTANCE FROM DISPERSAL POINT.—Manifestations of beetle dispersion as measured by maternal galleries in the trap trees at convergence points indicate a different rate of decrease as compared with the twig-crotch-feeding activity. Most galleries were found in trap trees nearest the dispersion point in 1940 and in 1941, as shown in table 4.

Table 4.—Distance and direction of trap trees from dispersion point, with average number of brood galleries of the smaller European elm bark beetle, Morristown, N. J.

DISTANCE FROM DISPERSILN POINT (FEET)	DIRECTION	AVERAGE NUMBER OF BROOD GALLERIES PER SQUARE FOOT OF BARK AREA	
		1940	1941
278	Easterly	13.8	28.9
310	Westerly	6.3	14.9
670	Easterly	6.7	17.8
844	Westerly	7.7	16.4
2059	Easterly	—	19.5
2851	Westerly	—	14.2
3749	Easterly	—	10.2
3749	Westerly	—	2.2

The average numbers of attacks were greater in 1941 than in 1940, possibly because of the greater number of beetles at the dispersion point. Termination of brood-gallery formation was at some distance more remote than 3749 feet from the dispersion point. Calculation of expected numbers of galleries (according to the regression formula) gave 20.2 and 8.1 galleries at 278 and 3749 feet, respectively. A further calculation, by means of the regression formula, assuming a rate of gallery decrease over a greater distance range of exactly the same magnitude as that over the observed range—a prediction to be taken with caution—gives slightly over 4 miles as the distance at which no brood gallery might be expected, which is not inconceivable in view of general field observations. A study of the regression curves from these data and from the report by Whitten (1938) show similar rates of curvilinearity.

STATISTICAL METHODS.—The data presented herewith have been studied by sta-

tistical analyses. The effects of distance have been found significant in all instances. Regression formulas were computed from the average percentages of crotch injuries in the distance classes (except the dispersion-convergence point in which the individual tree data were used) to measure the regression of injuries on increase of distance. These formulas employed the regular straight-line semilogarithmic method developed by Wadley & Wolfenbarger, and they indicate similar rates of injury decrease with distance increase for each set of dispersion data.

The evidence indicates that beetle dispersion of 3000 to 4000 feet, measured in terms of brood-gallery construction, reduces the number of galleries, but that the maximum dispersion range must be in terms of miles. These data emphasize the necessity for destruction of beetle infestations to eliminate or reduce dispersion of both the beetle and the causal organism of the Dutch elm disease.

SUMMARY.—Twig-crotch injuries by the smaller European elm bark beetle, *Scolytus multistriatus* (Marsham), were found more frequently around a dispersion point than around points where the beetles came for breeding. The average rates of crotch-injury decrease with distance increases from the dispersion point for 1940 and 1941 were similar. The incidence of twig-crotch injury around the dispersion-convergence point was similar to that around the dispersion point and dissimilar to the much lower rates around the convergence points. Brood galleries may be found as far as 4 miles from the place where the beetles that constructed them emerged.—4-1-43.

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Methods and Equipment for Fumigation of Clothing Infested with Body Lice[1]

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Last year the Bureau of Entomology and Plant Quarantine, at the request of the Surgeon General of the United States Army, undertook several lines of research to develop materials, methods, and equipment for the prevention or destruction of body lice infestations among the armed forces of the United States. This paper reports the equipment developed for fumigating clothing to destroy body lice. Studies on the other phases will be reported elsewhere.

FUMIGANT.—A fumigant was desired that would be rapid in action, noninjurious to clothing and equipment, effective at low temperatures, not too dangerous to handle, and without undesirable post-fumigation residues or unpleasant odors.

Biological tests[2] were made with several common fumigants, and only one, methyl bromide, was found to have the prime essential of requiring only a short fumigation period. Further tests demonstrated that methyl bromide also had the other desirable qualities sought—it is effective at temperatures down to the point where exposure to cold alone for the same period completely destroyed the lice, and it leaves no objectionable odors in fumigated clothing, except a slight musty smell in some instances.

Tests by the Quartermaster Corps and

[1] Early publication accorded this paper because of its war emergency value.

[2] The biological tests, which will be reported in another paper, were made by the senior author and by H. H. Richardson, James H. Kindler, W. A. Bruce, and W. E. Dove.

the United States Bureau of Standards revealed no injury to clothing or equipment by this gas. Previous studies with methyl bromide had shown it to be a relatively safe fumigant where proper precautions are observed in its use.[1] It was demonstrated by quantitative methods that, after fumigation, clothing could be freed of any injurious amount of absorbed gas by shaking out each garment in the open air. Tests made by the United States Public Health Service showed that clothing could be worn directly after fumigation without danger of skin irritation or injury from inhalation.

EQUIPMENT.—Features desired in the proposed fumigation equipment included lightness of weight, use of noncritical materials, self-contained operation, and small volume for shipping.

FIG. 1.—Rear panel of fumigating vault showing gasoline motor and blower drive, can of fumigant and applicator, and exhaust duct.

Two types of fumigation equipment were developed. For use at a base, a demountable vault was adapted from a light-weight type developed by the Bureau for fumigating plants and commodities under quarantine regulations. For field use, an individual fumigation bag was designed which holds about 25 pounds of clothing or equipment. The fumigant, when used in these bags, is contained in glass ampules.

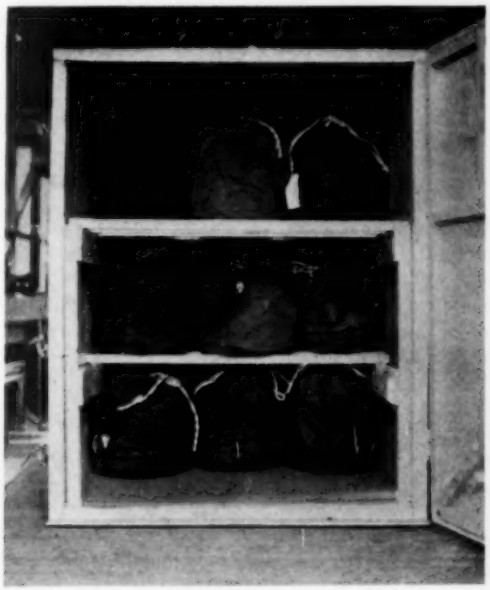

FIG. 2.—Load of clothing in vault ready to be fumigated.

DEMOUNTABLE VAULT.—The Army authorities desired to make the fumigation of clothing a part of a continuous procedure, and for that reason the size of each vault unit was limited to one that could be transported readily and unloaded quickly. The one first designed and demonstrated was of 250 cu. ft. capacity and held about 50 barracks' bags of clothing, but the size was later increased to 330 cu. ft. The vaults were intended for use in batteries.

The vault is built of half-inch plywood, with the top, sides, bottom, and ends as separate panels to be bolted together. One end serves as a door. All the operational equipment is placed on the back panel (Fig. 1) and consists of a motor-driven blower at the floor level, a duct from the blower toward the ceiling, and a vent at the end of the duct which, when open, diverts the air stream to the exhaust system. A gasoline motor operates the blower, which furnishes circulation during fumigation and venting afterwards. All joints are sealed with a nonhardening bituminous compound. The door and vents fit against molded sponge-rubber

[1] It was realized that any fumigant is toxic to humans to a greater or less degree, so a choice must be on a comparative basis.

FIG. 3.—Individual fumigation bag closed ready for use.

gaskets. The entire vault weights slightly more than 800 pounds.

The clothing to be fumigated is placed in barracks bags. In the vault the bags are set on removable racks in three layers, with about 6 inches of clearance between each layer (Fig. 2).

The fumigant is released from 1-pound cans by use of a proprietary applicator which punctures the can as a clamp is tightened, and delivers the contents into the air stream above the blower (Fig. 1).

In operation less than 10 minutes are necessary to load and close the valut, and at the end of the fumigation period less than 10 minutes are required to clear the gas from the vault to allow unloading.

INDIVIDUAL FUMIGATION BAGS.—The individual bags are designed to hold one soldier's uniform and blankets. The bags are made of relatively gastight material such as duck or sateen, coated with ethyl cellulose or neoprene (Fig. 3). A closure was desired which would be a part of the bag. This bag is closed by three times folding over the top edge, which is reinforced with strips of webbed canvas belting, and the folds are then secured by tape ties. This closure proved to be tight enough to retain a lethal concentration of the gas in the bag.

The clothing to be fumigated is put in the bag, the glass ampule of fumigant (Fig. 4) is placed in a special pocket provided for it, and the bag is closed and tied. The bag is then laid on its side, and the ampule is located and broken by stepping on it. At the end of the fumigation period the bag is opened in a well-ventilated place and the clothing dumped out. Fumigated clothing may be worn after 5 minutes' airing.—5-5-43.

FIG. 4.—Glass ampule of methyl bromide shown pulled part way out of its protective cloth casing. The fumigant is released by breaking the ampule inside of a pocket in the fumigation bag shown in figure 3. The cloth covering the ampule retains the pieces of broken glass.

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Diking as a Measure for Sand Fly Control in Salt Marshes

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In June 1936 the Saint Lucie County Sanitary District of Florida organized a project which is believed to be the first attempt to control salt-marsh sand flies, *Culicoides* spp., breeding in subtropical marshes. It was based on an experiment conducted by the Bureau of Entomology and Plant Quarantine in 1934, which demonstrated that salt marshes could be drained sufficiently to reduce greatly the breeding of these pests (Hull *et al.* 1939).

Fig. 1.—Ditch in mangrove marsh which has been dried to control sand fly breeding, Fort Pierce, Fla.

Fig. 2.—Ditch in pickleweed marsh which has been dried to control sand fly breeding, Fort Pierce, Fla.

This was accomplished by the use of dikes, to prevent periodic flooding by tides, supplemented with pumps to remove surface water. This paper is a report on the efficiency of the diking and pumping project conducted at Fort Pierce, Fla., from July 1939 through November 1941.

Description of the Marsh.—The Saint Lucie County Sanitary District selected the area on Hutchinson's Island lying across the Indian River from Fort Pierce as a typical sand fly breeding marsh. Here approximately 1,000 acres of salt-water-saturated muck sustains a heavy growth of red mangrove, *Rhizophora mangle* Lindl. (Fig. 1), black mangrove *Avicennia nitida* Jacq., and pickleweed, *Batis maritima* L. Fig. 2). In some places the last-named plant grows to a height of 3 feet, retards drying of the muck, and furnishes suitable shade for the development of sand fly larvae. Although the soil is primarily black muck, it varies in sand content and always contains a large amount of humus near the surface. Where the pickleweed predominates, the soil contains great quantities of roots and is more compact than that found under mangrove trees. Small patches of other types of vegetation occurring in southern Florida are present on the diked marsh; such as white mangrove, *Laguncularia racemosa* L., glasswort, *Salicornia* spp. L., sea oxeye, *Barrichia frutescens* (L.) DC., and leatherfern, *Acrostichum deneafolium* L.

In a previous paper it was pointed out that ditches dug in mangrove and pickleweed marshes for mosquito control resulted in a concentration of sand fly larvae within and upon the most parts of the ditch banks (Hull *et al.* 1934). The mosquito-control ditches caused a partial drying of the muck at some distance from them, especially during the low-tide periods. Where no ditches were present, sand fly breeding occurred abundantly

over extensive areas of low, wet marsh. Since the diked marsh had been ditched previously for mosquito control, it was necessary to dig new ditches only in certain places. When completed, 47,370 linear feet of dikes and supplementary ditches had been constructed in the area. Three pumping stations, with a combined discharge capacity of approximately 33,000 gallons of water per minute, were installed in the dikes near the river.

METHODS USED TO DETERMINE SAND FLY ABUNDANCE.—The intensity of breeding and the efficiency of control methods were determined by isolating 1-quart samples of soil in glass crystallizing dishes (Dove *et al.* 1932). The soil was thoroughly mixed and allowed to settle overnight in a crystallizing dish. On the following morning this dish was placed in a larger dish, and tap water was carefully poured into the larger dish until the smaller dish was completely submerged. The submerging of the soil stimulated the sand fly larvae to swim from the soil, and after 3 days almost all of them had migrated into the moat formed between the two dishes. From the moat the larvae were easily removed with a pipette and counted. Before counting the larvae, however, the samples were allowed to remain flooded 1 week.

To determine the number of adult sand flies emerging from the marsh, cloth-covered cages were used on the soil for capturing the flies as they emerged from their breeding places. The wooden frames of these cages are 2 feet square and 12 inches high. Along the lower edges of the sides of the cage a strip of sheet metal 12 inches wide is securely attached with screws. When the cage is placed in position, this metal strip is pushed down into the soil to prevent any larvae from migrating under the cage from soil not covered by the cage.

Previous to 1939 the comparisons of diked and undiked areas were made by collecting groups of soil samples from the two areas and counting the larvae isolated from them. This method of sampling indicated that sand fly breeding was greatly reduced by diking and lowering the water level. In June 1939 four plots of marsh were selected for sampling, one each from a diked and an undiked mangrove marsh and one each from a diked and an undiked pickleweed marsh. Later two plots were sampled from each type of marsh, making eight units in all. In selecting the plots consideration was given to elevation, location of ditches, type of soil, and drainage qualities. Pickleweed marshes are usually about 6 inches lower than mangrove marshes. Marshes as nearly comparable as possible were selected, and in all cases marshes that were slow to dry were used. Six sampling lines were established in each sampling unit, and samples of soil were obtained at stations situated as follows: In the ditch and 5, 10, 20, 40,

Table 1.—Sand fly larvae isolated from undiked and diked marshes at various distances from the drainage ditches. Fort Pierce, Fla., 1939–41.[1]

Distance from Ditch	July 1939 through Sept. 1940[2]			Nov. 1940 through Nov. 1941[3]		
	Undiked Marsh, Average Per Sample	Diked Marsh, Average Per Sample	Reduction in Sand Fly Larvae	Undiked Marsh, Average Per Sample	Diked Marsh, Average Per Sample	Reduction in Larvae
Feet	*Number*	*Number*	*Per Cent*	*Number*	*Number*	*Per Cent*
0	86.76	13.50	84.44	94.08	34.09	64.45
5	22.72	.55	97.61	—	—	—
10	10.50	1.22	88.57	12.31	.20	99.39
20	13.29	.45	96.63	7.47	.05	99.93
40	18.45	.11	95.41	8.85	.26	97.04
75	15.47	.09	99.45	5.85	.01	99.39
Averages	28.98	2.87	90.10	26.02	7.04	72.95

[1] This table is divided because the ditches contained more water during Nov. 1940 through Nov. 1941 than during July 1939 through Sept. 1940, when little pumping was done.

[2] Number of samples collected at each location in both undiked and diked marshes ranged from 103 to 134. Total samples from undiked marsh 755, from diked marsh 742.

[3] Number of samples collected at each location was 202 from both undiked and diked marshes. Total samples from undiked marsh 1,010, from diked marsh 1,010.

and 75 feet from the ditch. A large number of the ditches are only 150 feet apart, but it was found that when the ditches are more than 150 feet apart the moisture content of the more distant soil is approximately the same as that of soil 75 feet from the ditch. On each sampling line six stations were established at intervals of 20 feet. In the beginning all stations were sampled, but later, samples were collected from stations selected by random drawings of numbered cards.

number of larvae is shown in this table when the numbers of larvae isolated from undiked and diked marshes are compared.

From the data in table 1 we find that the smallest percentage of reduction of sand fly larvae was from samples collected in the ditches from both undiked and diked marshes. This means that the breeding of sand flies in salt marshes is determined by the amount of moisture present in the muck of the marshes.

The data on the number of larvae and

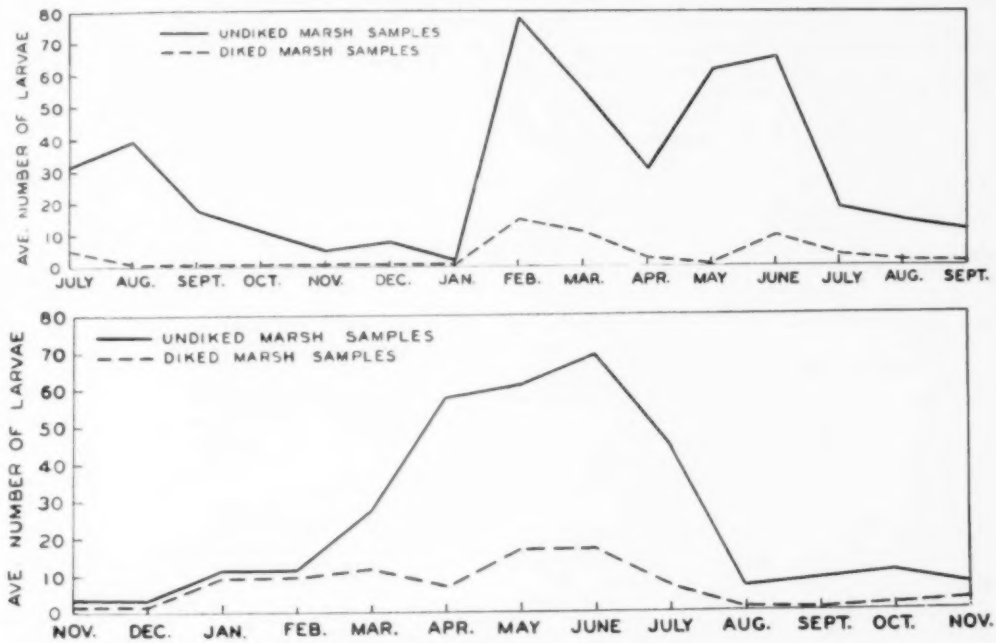

FIG. 3 (*Above*).—Sand fly larvae isolated from diked and undiked salt marshes. 1939–40.
FIG. 4 (*Below*).—Sand fly larvae isolated from diked and undiked salt marshes. 1940–41.

In November 1940 new sampling areas were selected in the same manner as in 1939, and sampling points were in similar relationship, except that the stations 5 feet from the ditch were discontinued. The spoil banks of the ditches in both diked and undiked marshes had begun to spread and caused soil 5 feet from the ditch to be of a slightly higher elevation in many places than the surrounding marsh.

SAND FLY LARVAE ISOLATED FROM UNDIKED AND DIKED SALT MARSHES.—A summary of the average number of larvae isolated from soil samples at various distances from the drainage ditches in the undiked and diked marshes is given in table 1. Also the percentage of reduction in the

soil samples was subjected to an analysis of variance. This analysis showed that the decrease in the number of larvae found in the diked marshes was highly significant, and that in 1939–40 a well-marked difference occurred between the number of larvae taken from the two marsh types. The mangrove marshes contained more larvae than the pickleweed marshes, but this difference was not so highly significant as the difference between diked and undiked marshes. In 1940–41 there was no significant difference between the mangrove and pickleweed marshes.

LARVAE ISOLATED FROM UNDIKED AND DIKED MARSHES.—Figure 3 shows the average number of sand fly larvae isolated

from samples each month, beginning in July 1939 and extending through September 1940. The principal peaks of infestation in the diked marsh coincide with those of the undiked marsh.

In figure 4 the average number of sand fly larvae found each month in undiked and diked marshes is shown graphically from November 1940 through November 1941. It should be noted again that generally the peaks of infestation in the diked marsh follow those of the undiked marsh. The infestation in the diked marsh as emerged from undiked marshes in 1940–41, representing a reduction of 82.78 per cent. This is compared with a reduction in larval population of ony 72.95 per cent as shown by the soil samples. The percentage of reduction is not so great when undiked and diked marshes are compared during certain periods of the year. This can be explained by the fact that the larvae migrate when a marsh is flooded. Should cages be placed just before or during or after a period of flooding, the cages will show less emergence of sand

Table 2.—Sand flies emerging under cages placed at various distances from the drainage ditches in the diked and undiked salt marshes. Fort Pierce, Fla., 1939–1941.

Distance from Ditch	Emergence July 1939 through Sept. 1940			Emergence Nov. 1940 through Nov. 1941		
	From Undiked Marshes	From Diked Marshes	Reduction in Emergence	From Undiked Marshes	From Diked Marshes	Reduction in Emergence
Feet	*Number*	*Number*	*Per Cent*	*Number*	*Number*	*Per Cent*
0	1,355	109	91.96	657	191	70.93
5	217	42	80.65	192	39	79.69
10	407	37	90.61	253	17	93.28
20	619	21	96.61	328	23	92.99
40	584	63	89.21	93	10	89.25
75	273	51	81.32	190	15	92.11
Total	3,455	323	—	1,713	295	—
Average	—	—	90.65	—	—	82.78

was higher in 1940–41 than in 1939–40 because less water was pumped from the diked area

SAND FLIES FROM CAGES IN THE UNDIKED AND DIKED MARSHES.—At the same time that the soil in the marshes was sampled for larvae, recovery cages were placed on the soil in undiked and diked marshes and at the same distances from the drainage ditches as the lines indicated for soil samples. In all, 24 cages were used in the undiked marsh and 24 were maintained in the diked marsh. The numbers of sand flies collected from the cages at various distances from the ditch are given in table 2.

The results obtained by the use of recovery cages show that the numbers of sand flies emerging from undiked and diked marshes (Table 2) are comparable, except that the percentage of reduction was slightly greater than was indicated by soil sampling (Table 1). The recovery cages show that only 17.22 per cent as many flies emerged from diked marshes flies than if they are placed on the soil at a time of normal tides. The larvae migrate from their normal habitat when it is too dry for them to survive. In 1939–40 only 9.35 per cent as many sand flies emerged under cages in the diked marsh, as compared with the number emerging under similar cages placed in the undiked marsh. In 1940–41 this rose to 17.22 per cent when the diked marsh remained wetter than the previous year. This shows that the amount of sand fly breeding in a salt marsh is governed by the amount of moisture in the muck of the marsh.

SUMMARY.—In 1936 the Saint Lucie County Sanitary District of Florida diked 1,000 acres of marsh directly east of Fort Pierce, for the control of salt-marsh sand flies and mosquitoes.

Samples of soil were collected and recovery cages were placed at the following distances from the drainage ditches: In the ditch and 5, 10, 20, 40, and 75 feet from the ditch.

During the period of July 1939 through

September 1940 an average of 28.98 sand fly larvae were isolated from the soil samples collected from the undiked marshes and an average of 2.87 larvae from samples collected from the diked marshes. If we consider the undiked marsh as 100 per cent infested, the degree of infestation was 90.10 per cent lower in the diked area. During the period of November 1940 through November 1941, when the Sanitary District pumped only for mosquito control, an average of 26.02 larvae were isolated from soil samples from undiked marshes, and an average of 7.04 larvae from diked marshes. If we again consider the undiked marsh as 100 per cent infested the degree of infestation was reduced 72.95 per cent.

If the emergence of adult sand flies from the undiked marsh, as shown by the recovery cages, 1939–40, is considered 100 per cent infestation, there was a reduction of 90.65 per cent by diking. If the emergence in the undiked marsh is considered 100 per cent infestation, then the infestation was reduced 82.78 per cent by diking during 1940–41, although no special effort was made to dry the diked marshes.—1-4-43.

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Diking and Pumping for Control of Sand Flies and Mosquitoes in Florida Salt Marshes

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Early in 1926, in accordance with the provisions of a special act of the Florida State Legislature, mosquito control work was organized and the St. Lucie County Sanitary District created. Near Fort Pierce the ditching of mosquito-breeding areas was undertaken as fast as funds were made available through the local taxing unit. Ditches, 20 inches wide and 20 inches deep, were dug by hand 150 to 310 feet apart through the marsh, with openings into Indian River. These ditches were designed for free penetration of predatory minnows, *Gambusia* spp., to all parts of the marsh. Three hundred miles of hand-dug and dynamite-blasted ditches, or about 250 feet of ditch per acre, were completed on marshland capable of producing mosquitoes.

In 1932 the Bureau of Entomology and Plant Quarantine of the United States Department of Agriculture started experiments on the control of sand flies near Fort Pierce. These experiments demonstrated that diking a salt marsh to exclude tides and using pumps to remove rain water would dry the marsh soil and therefore greatly reduce sand fly breeding. One hundred acres were effectively dried with the first pumping unit, and in view of these results the Sanitary District diked a marsh area of 1000 acres and installed two additional pumping stations at intervals in the dike. After heavy rainfalls the pumps kept the water confined to the ditches so that the fish could feed on mosquito larvae present. Since the sand fly and mosquito control project of the Sanitary District continues to function effectively, and because other communities show interest, in undertaking similar work, it seems advisable to outline some of the details on construction and costs of this project.

DESCRIPTION OF AREA.—The marsh located on Hurchinson's Island, directly opposite Fort Pierce, was chosen as the experimental area because it was in close proximity to a fairly large community. It is a narrow reef or peninsula ranging in

width from 1.5 miles to a few hundred yards with very little elevation. The highest points are a few oak and palmetto hammocks, not over 10 feet above sea level. In this area 1,000 acres of marsh and an additional 200 acres of high sand beaches and hammocks had been ditched with 192,000 feet of mosquito control ditches excavated by hand labor and 57,000 feet of ditches formed by dynamite explosions.

These marshes normally were covered by tides, which ranged from a few inches to 2 feet during a full moon or even to as much as 3 feet when a full moon was accompanied by a northeast wind. Extensive areas of red mangrove, *Rhizophora mangle* Lindl., and pickleweed, *Batis maritima* Lindl., and patches of black mangrove, *Avicennia marina* Jacq., occur in large plots, in fringes along the shore, or in low connecting land between the ponds and near the hammocks.

CONSTRUCTION OF DIKES.—The diking was accomplished with a three-eighths yard drag line having a 27-foot boom and a three-fourths-yard drag line having a 37-foot boom. Two diking machines were operated on five mats 7 by 14 feet and 6 inches thick constructed of heavy timbers. When ditches or sloughs were encountered the mats were laid on top of six or eight long palmetto logs. Work continued even when several inches of tide water covered the mats, although at a slower speed.

Firm soil from the top of the marsh was piled at the outer edges of the proposed dike and the space between these piles filled in with soft silt from the lower excavations. The result was a partial silt core in the dike, which dired with very little settling. At first the top soil of the dike was leveled by hand, but this practice was discontinued since the drag line could accomplish the same purpose by pulling the mats over the shoulders of the dike. When the first dike was made, to enclose pumping unit 1, consisting of about 100 acres, the material flowed badly in places and the drag-line operator dug deeper than was desired. The deep excavations cut into an underlylng sand layer and caused a seepage of eater. The difficulty was not due to the use of a small-size bucket on the drag line but to the short length of the boom. In the course of time the seepage silted up and at present very little of it is in evidence.

Some trouble resulted from erosion due to heavy rains before vegetation was established on the dike. To overcome this, about a mile of the dike was planted in Bermuda and St. Augustine grass. The latter seemed more desirable because it spread rapidly and extended to the edges of the dike, where it met the high tides. All plantings were discontinued when native plants covered the dike. Almost 50 kinds of native plants are now found on one section of the dike. Normally several months are required for plants to grow on the dike, but some become established soon enough to prevent any great erosion.

The size of the dikes and supplementary ditch are given in table 1.

Table 1.—Construction dimensions of dikes, canals, and ditches of St. Lucie Sanitary District.

	Size in Feet	Lineal Feet	Cubic Yards
Main dike and canal	25×18×4	23,970	76,225
	16×4	4,335	10,275
Supplementary dike	12×4	225	400
Supplementary canal	10×3	17,800	19,777
Small feeder ditches	1×1 to 2×1	1,040	928
Total	—	47,370	107,605

The construction cost of the dikes and canals was as follows:

Moving drag line to project	$ 121.92
Operating drag line, $1.00 per hour	3,227.48
Fuel, gasoline	1,023.67
Grease and oil	26.31
Reconditioning drag line and repair	2,857.73
Mats	35.28
Supervision, tools, and transportation	1,860.74
Miscellaneous materials	37.04
Labor, clearing right-of-way (43.5 acres)	2,119.20
Total	$11,309.37

DESCRIPTION OF PUMPING UNITS.—Pumping units were installed at intervals along the dike. The pumps, which were assembled locally, are similar to those used throughout southern Florida, where drainage is necessary in low agricultural areas. They are powered by automobile motors, are capable of removing a large volume of water when the lift is low, and cost little to install.

The pump impeller (Fig. 1) is a heavy iron disk 30 inches in diameter, attached as a wheel to a rear automobile housing.

One side of the housing is removed, and the differential locked so that the axles turn together. Heavy metal vanes, 4 by 10 inches, slightly curved on the long surface are welded at 2-inch intervals near the periphery and along the radii of the disk, the 10-inch curved edges therefore making contact with the bottom of the disk and their convex surfaces facing the direction of rotation. The assembly is suspended in such a way that the flat surface of the disk is below and parallel to the water surface and the torque tube above the ground and in position for attachment to a drive shaft or pulley of the power plant.

Around the suspended pump wheel is a concrete sump extending from below the water to the top of the dike with enough clearance around the pump wheel., or impeller, to allow free circulation of water. The pump receives the water from the canal through a circular opening in the false bottom of the sump. This opening is directly beneath and one-fourth inch below the impeller. An opening approximately 48 inches square in the side of the sump extends into the sluiceway. Its

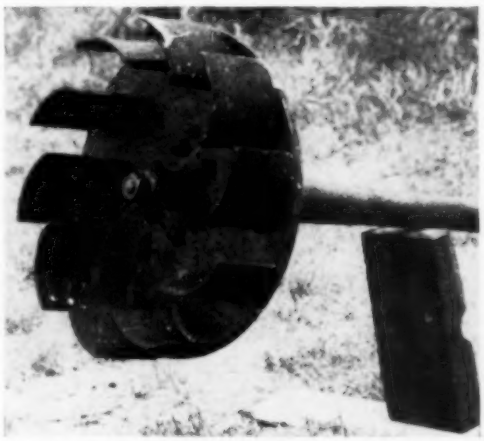

FIG. 1.—Impeller head of pump used in a dike for control of sand flies and salt-marsh mosquitoes.

corners are rounded to reduce eddying of the water while the pump is in operation.

The canal end of the sluiceway, which extends through the dike from the canal to the river, is closed by automatic tide gates. The sluiceway of pumping unit 2 is built of solid concrete on the sides and bottom and measures 7 by 25 feet. It has one pump, a tide gate 2 by 3 feet next to the pump, and a tide gate 1 by 6 feet at the end of the sluiceway. The pumping unit 3 (Fig. 3) has a sluceway 19 by 20 feet. The sides are of reinforced concrete blocks and the floor of solid concrete. There is a pump and tide gate, 1.5 by 5.5 feet, on each side and three tide gates on

FIG. 2.—Pumping station unit 3 during its construction at Fort Pierce.

the end. The reinforced-concrete tide gates were designed long and narrow because of the low tidal range.

The operation of the pump is simple. When power is applied, the impeller revolves and the water between the blades is forced out by centrifugal action. A head of water is built up in the sump, and, when the pressure becomes greater than that of the water in the river, the tide gate opens and the water flows out. As the water flows through the hole in the false bottom, it is caught in the centrifugal action of the wheel and thrown out. These pumps move from 8,000 to 12,000 gallons of water per minute, depending upon the size of the impeller and motor used. The three pumping stations have a combined capacity of approximately 33,000 gallons per minute when pumping against a head of 3 feet. This type of pump has been used in southeastern Florida for several years, but it had not been tested in salt marshes. The first pumping station was an experiment, but it was successful, and the second and third units therefore followed. The third unit has proved to be the most efficient. A photograph made during its construction shows some of the details (Fig. 2). Installation costs of all pumping stations are given in table 2.

Table 2.—Cost of installing pumping stations.

	Materials	Labor
Pumping unit 1		
Tools and dynamite	$ 31.45	
Pump sump	69.08	
Pump and house	41.07	
House and pump		$ 35.00
Overhauling sump		36.09
Motor	50.00	
Asphalt-coated pipe, 20 feet by 30 inches	56.00	
Pump	100.00	
Tide gate		
Automatic "Calco" tide gate	83.65	
Total	$431.25	$ 71.09
Pumping unit 2		
Materials and labor for sluiceway 7 by 25 feet with 6-foot walls and tide gates	364.32	200.00
Pump	90.00	100.00
Motor	50.00	
Total	$504.32	$300.00
Pumping unit 3		
Materials and labor for sluiceway 19 by 20 feet with 6-foot walls and tide gates	664.51	300.00
Pumps (2)	278.50	
Motors (2)	195.07	
Total	$1,138.08	$300.00

COST OF OPERATING PUMPS.—The complete cost of operation of all three pumps for 2 years is given in table 3. The cost of operators is considerable and can be reduced only by the use of larger stations instead of several small stations. The average cost per hour in 1939 was 25.1 cents and in 1940, 39.2 cents. The difference was due principally to repairs to the motors and replacement of one motor.

SUMMARY.—About 1,000 acres of salt marsh and 200 acres of high ground were diked and pumps installed for the control of sand flies and mosquitoes at Fort Pierce, Fla. The types of dikes, impeller pump, and tide-gate installations found most satisfactory are described and the costs analyzed. A total of 47,370 feet of dikes and canals was constructed at a cost of $11,309.37.

Three pumping stations with automatic tide gates and impeller type pumps were installed at a cost of $1,438.08. The three units have an approximate pumping capacity of 33,000 gallons of water per minute against a head of 3 feet.

The pumps were operated at an average cost of 25.1 cents per hour in 1939 and 39.2 cents per hour in 1940, the difference being due to the cost of repairs and the replacement of one motor.—1-4-43.

Table 3.—Cost of operating pumps.

Pump No.	Hours Pumped	Gallons of Gas Used	Cost of Gas	Cost of Oil	Cost of Repairs	Cost of Operators	Total Cost
			1939				
1	5	—	$270.40	$6.84	$12.55	$135.00	$424.79
2	138.75	259					
3 N.	323	739					
3 S.	335	692					
Total	801.75	1,690					
			1940				
1	60	111	477.17	45.00	429.73	149.35	1,101.25
2	221	408					
3 N.	474	1,080					
3 S.	528.50	1,117					
Total	1,283.50	2,716					

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The Use of Sulfur and Sulfur Compounds in the Control of Poultry Lice[1]

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The control of poultry lice is essential to the economic operation of successful poultry farms. This is due to the fact that when abundant the attack of these ectoparasites greatly reduces the vigor of laying and breeding stock. Some investigational work has been performed by other workers relative to the control of these parasites. Thus we know that sodium fluoride, sulfur, and pyrethrum dusts are effective. Likewise sodium fluoride, pyrethrum, and nicotine sulfate dips will provide relief. However, these methods are quite laborious as they require handling of the individual birds by the operators. More satisfactory methods are desirable and necessary.

The authors have investigated the use of sulfur and sulfur compounds in the control of these pests. These investigations were performed during the years of 1939, 1940, and 1941. The funds for these investigations were supplied by the Freeport Sulfur Company.

MATERIALS AND EQUIPMENT.—A stock pen 20 feet by 30 feet was used to maintain birds before being placed in experimental areas. Experiments Nos. 1, 2, 3, 4, and 5 were conducted in test pens 9 feet wide by 20 feet in length. The pens faced north and south. A small house with a southern exposure was placed at the north end of each pen. Vegetation was removed from all pens. There was no shade available for any of the birds in the eight pens. In most instances they were permitted free access to the houses during daylight hours.

In experiment No. 6 the birds were confined in 2 feet by 2 feet by 2 feet apartment cages. Experiment No. 7 was conducted in a combination inside and outside pen. The inside pen was connected with the outside pen by a runway. The outside pen was 1½ feet by 6 feet by 6 feet. It was elevated 2 inches above the ground. In experiment 8 wire test pens with dimensions of 2.5 feet by 2.5 feet by 2 feet were employed. Portable coops were used in experiment 9.

Maximum and minimum thermometers were used in recording temperatures three times daily. Relative humidity was determined with a precision hygrometer. One-gallon metal water containers were used in the outside pens. Specially constructed wooden feed hoppers were employed.

Commercial flour sulfur and dusting sulfur were employed in the tests. The dusting sulfur was of a degree of fineness that would permit 93 per cent to pass through a 325-mesh screen and 90 per cent of the flour sulfur would pass through an 80-mesh screen. The dusting sulfur was conditioned with clay.

ESTIMATION OF INFESTATIONS.—Mature white leghorn hens were used in all experiments. These were in relatively good health and well infested with one or more species of lice. Careful observations were made of each bird prior to the institution of the tests. Insect population estimates were recorded of the "shaft louse," *Menopon pallidum* Nitz., the "fluff louse," *Goniocotes hologaster* Nitz., and the "body louse," *Menopon biseriatum* Piaget. These three species are indicated in all tables by the letters *S*, *F*, and *B* respectively.

The degree of louse infestation was recorded as follows: 0—no infestation; 1—light (approximately 1 to 25 lice); 2—medium (approximately 25 to 50); 3—heavy (approximately 50 to 75); 4—very heavy (approximately 75 to 100 or more).

INTERNAL SUBMISSION OF SULFUR.—The effect of internal submission of sulfur upon chicken lice has been a debated question. Some workers have indicated that their results were positive.

A series of five experiments were conducted. These extended over a one-year period. The sulfur was administered in large capsules, which were dipped in water to facilitate swallowing.

In experiment No. 1 dusting sulfur was administered in 1.5 gram doses three times daily before feeding. After a three-week period this daily dosage was increased to 9 grams administered three times daily. In experiment No. 2, flour

[1] Early publication secured by payment of costs of printing.

Table 1.—Internal submission of sulfur.

Insp. No.[1]	Experiment 1 June 10–August 8 4.5–9 Grams Daily Bird No. 5491 S B F	5460 S B F	5463 S B F	Experiment 2 August 8–Sept. 3 4.5 Grams Daily Bird No. 5455 S B F	5441 S B F	5402 S B F	Experiment 3 Sept. 12–Oct. 10 9 Grams Daily Bird No. 5499 S B F	5174 S B F	5166 S B F	Experiment 4 Oct. 24–Nov. 21 9 Grams Daily Bird No. 5172 S B F	5138 S B F	5142 S B F	Experiment 5 Mar. 19–Apr. 23 9 Grams Daily Bird No. 5626 S B F	5622 S B F
1	3 1 2	3 1 1	3 1 1	2 0 1	1 0 1	3 0 1	3 2 1	3 0 1	2 2 2	2 1 2	3 0 1	1 2 1	4 0 4	4 0 2
2	3 1 1	3 1 1	2 1 1	2 0 1	0 0 1	3 0 1	3 3 1	3 1 1	3 2 1	2 2 2	2 0 1	1 2 1	4 0 4	4 0 4
3	1 1 1	1 1 1	2 1 1	2 1 1	1 0 1	2 0 1	3 3 0	3 1 1	3 1 1	2 2 2	3 1 2	1 1 1	4 0 4	4 0 4
4	2 2 1	2 1 1	2 0 1	2 1 0	1 1 1	2 1 1	3 2 2	2 0 0	3 0 1	3 2 1	3 2 1	2 2 2	4 0 4	4 0 4
5	3 1 0	3 2 0	2 1 0	3 0 1	1 0 1	1 0 1	3 1 2	3 0 0	3 0 0	3 2 0	3 1 0	2 1 2	4 0 4	4 0 4

[1] Inspections weekly.

sulfur was administered three times daily in 1.5 gram capsules for a period of 5 weeks. In experiments 3 and 4 dusting sulfur was administered twice daily in 4.5 gram capsules before feeding. Experiment No. 5 was a duplicate of No. 4 except the birds were permitted access to feed at all times, and the daily administration of dusting sulfur was continued for a period of only two weeks.

Results of the five experiments are given in table 1. In some instances there was some decrease in the lice populations between the first and last inspections. For example bird No. 5491 in experiment 1 had a decrease in estimated population of fluff lice from 2 to 0. Similar results were obtained on bird 5166 in experiment 3, and bird 5172 in experiment 4. However, rather similar variations were recorded for check birds 5425, 5118, and 5448, table 8. Therefore it seems that all decreases in the populations of lice were due to normal fluctuations.

The administration of sulfur over a period of time results in severe diarrhea. There was general loss of vitality, and a tendency to consume greater quantities of water. In some instances there was a great increase in total lice populations. These increases will not be evident in the tables. For example in experiment 5 the total louse population increased from approximately 200 (4) to 4000 (4) during the 5-week observation period.

FED OVER SULFUR, IN STEEL BARREL.—The birds in these experiments were forced to feed in a steel barrel over a layer of dusting sulfur. This was accomplished by cutting a hole in the side of the barrel and inserting a wire platform suspended approximately 6 inches from the bottom. A layer of sulfur was placed on the bottom of the barrel and the feed hopper was placed on the wire platform. The birds were standing in a partially enclosed barrel over sulfur during the entire feeding process.

There was some fluctuation in lice populations in some of the experiments. However, the decreases in populations were not very significant. Results are given in table number 2, and checks in table number 8.

SULFUR FEED, IN WOODEN BARREL.—One half of a 60-gallon wooden barrel was used as a feed hopper. The mash containing a definite percentage of dusting sulfur was made available in the barrel. It was necessary for the birds to stand in the mash while feeding. The objective in these tests was to give the birds ample opportunity for external contamination with sulfur.

In experiment 1 the birds were supplied a 5 per cent sulfur-mash feed for 2 weeks and then a 10 per cent sulfur-mash feed for 3 weeks. In experiment 2 a 5 per cent feed was supplied for 5 weeks. In experiments 3 and 4 a 10 per cent feed was supplied for 5 weeks, and in experiment 5 a 10 per cent feed was supplied for 2 weeks.

Results for these tests are given in table 3 and checks in table 8. In some instances

Table 2.—Birds fed over dusting sulfur, in steel barrel.

Insp. No.	Experiment 1 June 10–August 8 Bird No. 5465 S B F	5476 S B F	5458 S B F	Experiment 2 August 8–Sept. 3 Bird No. 5455 S B F	5441 S B F	5402 S B F	Experiment 3 Sept. 12–Oct. 10 Bird No. 5499 S B F	5174 S B F	5166 S B F	Experiment 4 Oct. 24–Nov. 21 Bird No. 5169 S B F	5156 S B F	5171 S B F	Experiment 5 Mar. 19–Apr. 23 Bird No. 5637 S B F	5640 S B F
1	3 1 1	3 1 2	2 1 1	2 0 1	1 0 1	3 0 1	3 2 1	3 0 1	2 2 2	2 1 0	2 1 2	1 2 1	4 0 3	1 0 2
2	2 1 1	2 1 1	2 1 1	2 0 1	0 0 1	3 0 1	3 3 1	3 1 1	3 2 1	2 0 0	2 2 2	2 1 1	4 0 3	1 0 2
3	1 2 1	3 1 2	1 0 0	2 1 1	1 0 1	2 0 1	3 3 0	3 1 1	3 1 1	2 1 0	2 3 2	2 1 1	4 1 4	4 0 4
4	2 2 1	3 0 3	2 2 1	2 1 0	1 1 1	2 1 1	3 2 2	2 0 0	3 0 1	2 1 1	2 3 1	2 1 1	4 0 4	4 0 4
5	2 1 1	2 1 4	2 1 1	3 0 1	1 0 1	1 0 1	3 1 2	3 0 0	3 0 0	2 2 1	2 2 0	2 1 0	4 0 4	4 0 4

Table 3.—Sulfur feed, in wooden barrel.

	Experiment 1 June 10–August 8 5–10% Sulfur Feed									Experiment 2 August 8–Sept. 3 5% Sulfur Feed									Experiment 3 Sept. 12–Oct. 10 10% Sulfur Feed									Experiment 4 Oct. 24–Nov. 21 10% Sulfur Feed									Experiment 5 Mar. 19–Apr. 23 10% Sulfur Feed					
	Bird No.									Bird No.									Bird No.									Bird No.									Bird No.					
Insp.	5470			5498			5459			5432			5411			5413			5132			5119			5153			5160			5108			5181			5642			5643		
No.	S	B	F	S	B	F	S	B	F	S	B	F	S	B	F	S	B	F	S	B	F	S	B	F	S	B	F	S	B	F	S	B	F	S	B	F	S	B	F	S	B	F
1	4	2	2	4	2	4	4	1	4	3	1	1	2	0	1	1	0	0	3	0	1	3	0	1	3	2	0	3	2	1	2	3	1	1	1	1	4	1	4	4	0	2
2	2	1	2	4	1	2	4	1	3	3	1	1	2	0	1	1	0	0	3	1	0	2	1	0	2	2	0	3	1	1	2	2	1	1	0	1	4	0	4	4	0	2
3	4	2	3	4	2	2	4	3	4	2	0	1	2	0	1	0	0	0	3	1	0	[1]			2	0	1	2	1	0	2	1	1	2	0	0	4	0	4	3	0	2
4	4	1	3	4	1	3	4	3	4	2	1	1	2	2	2	0	0	0	2	1	0				2	0	0	2	0	0	1	2	1	2	1	1	4	0	4	3	0	2
5	3	1	3	4	1	1	4	1	2	1	0	0	1	0	0	1	0	0	2	0	0				1	0	0	2	0	1	1	2	1	2	0	1	4	0	4	4	0	2

[1] Bird number 5119 died.

there was a reduction in lice populations. However, these reductions were not sufficient to indicate whether they were ordinary fluctuations or due to contamination. It is quite evident that the contamination was not sufficient to give good control. If a small quantity of scratch feed had been added to the barrel at regular intervals it might have resulted in sufficient scratching by the birds to cause the necessary body contamination.

SULFUR FEED, IN HOPPERS.—In these tests a 6- by 18-inch feed hopper was used in supplying sulfurized feed. In experiment 1 a 5-per cent flour-sulfur feed was supplied for 2 weeks and a 10-per cent for the remaining 3 weeks. In experiment 2 a 5-per cent dusting sulfur feed was supplied for 5 weeks. In experiments 3 and 4 a 10-per cent dusting sulfur feed was supplied for 5 weeks. In experiment 5 a 10-per cent dusting sulfur feed was supplied for 2 weeks and then the birds were fed regular mash for the remainder of the experiment. The objective was to determine whether birds fed a mash containing sulfur in a hopper would become sufficiently contaminated to result in a worth while control of lice.

Results of five experiments are recorded in table 4 and checks in table 8. In experiments 1, 2, 3, and 4 there were definite fluctuations. In the first three experiments there were gradual decreases in most instances, while in experiment 4 there were some increases. The most significant thing about these tests was the noted reduction in lice populations in the neck region. This region had a better opportunity for contamination under the conditions of the experiments. In experiment 5 there was no variation.

SULFUR FEED, BIRDS CAGED INSIDE.—The birds in this test were caged in small wire apartment cages and fed a mash feed containing 10 per cent of dusting sulfur for 2 weeks. They were retained inside an experimental building. The regular feed was supplied after 2 weeks. Results are given in table 5. It will be noted that there was fluctuation especially in the populations of shaft and fluff lice on bird number 36,421. The body lice remained constant on this bird but decreased on bird number 85,583. The checks show no such reduction. These results tend to substantiate previous tests conducted by the authors. It appears that there is a better opportunity for contamination under this condition than under normal outdoor pen conditions.

LARGE SCALE FEED TESTS.—A large scale diet test was made between June 19 and August 15. Twenty-five birds were used in the tests. Only the shaft and body lice were abundant. The test birds were provided with a 5 per cent dusting sulfur mash diet for 3 weeks. There was no reduction in lice populations. The sulfur concentration was then increased to 10 per cent for a period of 2 weeks. There was only a very slight variation in populations

Table 4.—Sulfur feed, in hoppers.

	Experiment 1 June 10–August 8 5–10% Sulfur Feed									Experiment 2 August 8–Sept. 3 5% Sulfur Feed									Experiment 3 Sept. 12–Oct. 10 10% Sulfur Feed									Experiment 4 Oct. 24–Nov. 21 10% Sulfur Feed									Experiment 5 Mar. 19–Apr. 23 10% Sulfur Feed					
	Bird No.									Bird No.									Bird No.									Bird No.									Bird No.					
Insp.	5475			5466			5403			5444			5410			5412			5419			5163			5193			5123			5190			5197			5644			5648		
No.	S	B	F	S	B	F	S	B	F	S	B	F	S	B	F	S	B	F	S	B	F	S	B	F	S	B	F	S	B	F	S	B	F	S	B	F	S	B	F	S	B	F
1	4	1	4	4	1	4	3	1	1	3	1	2	3	1	2	1	0	1	3	1	1	2	0	1	1	1	0	1	1	1	3	0	1	2	0	1	2	0	2	4	0	4
2	4	1	2	2	1	2	2	1	1	3	1	1	3	1	2	1	0	1	3	1	0	1	0	1	1	1	1	1	0	1	2	0	1	2	0	1	2	0	2	4	0	3
3	2	1	4	2	1	3	2	1	1	3	1	0	2	2	1	1	1	1	3	1	1	1	0	0	1	1	1	1	0	0	2	1	0	1	1	1	2	0	3	3	0	4
4	2	2	4	3	1	1	2	1	1	2	1	0	2	1	0	2	0	1	3	2	1	1	1	0	2	1	1	1	2	1	3	2	1	1	2	1	2	0	2	3	0	4
5	1	1	2	2	2	2	2	1	1	2	0	0	1	0	1	1	0	1	2	1	1	1	0	0	2	0	0	1	2	1	3	1	1	2	2	1	4	0	2	4	0	4

Table 5.—Sulfur feed dusting and internal submission.

Insp. No.	Experiment 6 April 7–May 12 Dusted Daily with 10% Sulfur Feed Bird No. 86636 S	B	F	87170 S	B	F	Experiment 6 April 7–May 12 10% Sulfur Feed Caged Inside Bird No. 36421 S	B	F	85583 S	B	F	Experiment 6 April 7–May 12 Check Bird No. 86617 S	B	F	86816 S	B	F
1	2	0	3	2	1	1	3	4	1	3	2	1	3	4	4	2	1	1
2	1	1	1	0	0	1	2	3	4	2	0	1	4	4	4	2	2	3
3	0	0	0	0	0	0	2	2	3	2	1	1	4	4	4	3	2	4
4	0	0	0	0	0	0	1	4	1	1	1	0	4	4	4	4	3	3
5	0	0	0	0	0	0	1	4	1	1	1	1	4	4	2	4	3	2
6	0	0	0	0	0	0	0	4	1	1	0	2	4	4	3	4	1	4

following this method of feeding. This reduction seemed to occur in the neck region. For the remainder of the 3-month test period a 5 per cent sulfur feed was used. There was no additional decrease in populations.

External Dusting with 10 Per Cent Sulfur Feed.—The birds used in these tests were confined inside in apartment cages. They were dusted daily for 2 weeks with a handful of feed containing 10 per cent of dusting sulfur. Results are given in table 5. The decrease in all species of lice after the first week was very great. The third and all subsequent inspections revealed a complete freedom from lice. This proves that ample contamination of the body with sulfur treated feed will result in good control.

External Dusting with Sulfur.—In experiments 1 and 2 each bird was dusted with 4.5 grams of dusting sulfur each morning. In experiments 3 and 4 each bird was dusted semi-weekly in the mornings with 9 grams of sulfur. In experiment 5, 9-gram applications of sulfur were made daily for 2 weeks.

Results are given in table 6. It will be noted that 100 per cent control was obtained in a period of 2 to 4 weeks after the first treatments. These results confirm previous experimental work of other workers relative to the value of sulfur dusting in the control of chicken lice.

Soil Treatment with Sulfur.—In experiments 1 and 2 the soil was dusted with dusting sulfur at the rate of 5 pounds per 100 square feet. This treatment was repeated every 2 weeks. In experiment 3 sulfur was applied at the rate of 10 pounds per 100 square feet. In experiment 4 the application was 10 pounds of sulfur per 100 square feet semi-weekly. In experiment 5 the sulfur was applied once at the beginning of the experiment. The application was at the rate of 10 pounds per 100 square feet.

Observations revealed that the birds dusted themselves frequently in the sulfur-treated sandy soil. When population counts were made sulfur was detected among the feathers and on the body of the birds. Results of these tests are recorded in table 7. It will be noted that there was a striking reduction in the lice populations to a point of extermination in experiments 1, 2, 3, and 5. The latter received only one treatment and yet results were excellent. The control in experiment 4 was not so good. This might possibly have been due to a failure of the birds to dust themselves properly or to the season of the year.

Table 6.—External dusting with sulfur.

Insp. No.	Experiment 1 June 10–August 8 4.5 Grams Daily Bird No. 5478 S	B	F	5471 S	B	F	5474 S	B	F	Experiment 2 August 8–Sept. 3 4.5 Grams Daily Bird No. 5423 S	B	F	5418 S	B	F	5451 S	B	F	Experiment 3 Sept. 12–Oct. 10 9 Grams Semi-Weekly Bird No. 5416 S	B	F	5167 S	B	F	5184 S	B	F	Experiment 4 Oct. 24–Nov. 21 9 Grams Semi-Weekly Bird No. 5109 S	B	F	5178 S	B	F	5180 S	B	F	Experiment 5 Mar. 19–Apr. 23 9 Grams Daily Bird No. 5652 S	B	F	5653 S	B	F
1	3	1	2	3	1	2	1	0	1	2	1	1	2	0	1	2	2	3	3	2	1	3	0	1	2	1	1	3	2	1	2	0	1	2	1	0	4	0	4	2	0	3
2	1	1	1	1	1	2	1	0	0	0	0	0	0	0	0	1	0	2	2	2	0	2	1	0	1	1	0	2	1	1	2	0	1	2	0	0	2	0	1	1	0	1
3	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	1	1	0	1	1	0	1	0	0	1	0	0	1	0	1	1	0	0	1	0	0	1	0	1	0	0	0
4	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 7.—Soil treatment with sulfur.

	Experiment 1 June 10–August 8 5 lbs. per 100 sq. ft. Bird No.									Experiment 2 August 8–Sept. 5 5 lbs. per 100 sq. ft. Bird No.									Experiment 3 Sept. 12–Oct. 10 10 lbs. per 100 sq. ft. Bird No.									Experiment 4 Oct. 24–Nov. 21 10 lbs. per 100 sq. ft. Bird No.									Experiment 5 Mar. 19–Apr. 23 10 lbs. per 100 sq. ft. Bird No.					
Insp. No.	5464			5494			5461			5431			5409			5433			5158			5185			5135			5143			5114			5102			5662			5669		
	S	B	F	S	B	F	S	B	F	S	B	F	S	B	F	S	B	F	S	B	F	S	B	F	S	B	F	S	B	F	S	B	F	S	B	F	S	B	F	S	B	F
1	2	1	3	2	3	1	1	0	1	2	0	1	4	1	2	1	0	1	3	1	1	2	0	1	2	1	1	1	0	1	1	1	2	2	1	1	4	0	3	3	0	4
2	1	1	3	1	2	1	1	0	1	1	0	1	3	1	1	2	3	1	3	2	1	1	0	1	1	1	1	1	0	1	1	1	1	2	1	0	4	0	2	2	0	4
3	0	1	0	0	3	1	0	0	1	1	0	0	2	1	2	2	2	0	2	1	1	1	0	0	1	1	1	1	0	0	1	1	1	2	0	0	2	0	2	1	0	1
4	0	0	1	0	1	0	0	0	1	0	0	0	1	0	1	1	1	1	1	1	0	0	0	0	0	0	0	1	0	1	1	0	0	2	0	0	1	0	1	0	0	1
5	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	1	1	0	0	0	0	0	0	0	0	1	0	0	1	0	1	2	0	1	0	0	0	0	0	0

It is quite likely that the control effected is due to contamination of the body by normal dusting and not to volatilization of sulfur. Possibly if only the areas frequented by the birds for dusting purposes were heavily treated with sulfur a good control of lice would result.

SOIL TREATMENT UNDER WIRE.—The birds used in this experiment were confined in a combination inside and outside pen. The outside part was elevated 2 inches above the ground. The soil under the oustide part of the cage was treated frequently with sulfur at the rate of 10 pounds per 100 square feet. Results are given in table 9. It will be noted that there was no severe fluctuation of lice populations. The temperatures were relatively high during the test. This indicates that birds must actually come in contact with treated soil to obtain any value.

LARGE SCALE SOIL TREATMENT TESTS.—Two soil treatment tests were made using a number of birds. In one test the soil was treated with sulfur at the rate of 5 pounds per 100 square feet and the house was dusted with 5 pounds of sulfur. This treatment was repeated every 10 days. The results were negative. Twenty birds were used in each test.

In the second soil treatment test the soil was treated with 10 pounds of sulfur

Table 8.—Checks, no treatment.

	Experiment 1 June 10–August 8 Check Bird No.									June 10–August 8 Check Bird No.									Experiment 2 August 8–Sept. 3 Check Bird No.								
Insp. No.	5469			5406			5455			5467			5473			5479			5425			5430			5437		
	S	B	F	S	B	F	S	B	F	S	B	F	S	B	F	S	B	F	S	B	F	S	B	F	S	B	F
1	3	1	2	4	3	1	4	3	2	3	1	2	3	1	2	3	1	3	3	1	1	3	0	1	3	0	1
2	3	1	1	3	1	1	3	1	1	2	1	2	4	1	2	3	1	2	4	3	2	4	1	2	4	1	2
3	4	2	2	3	2	2	3	1	2	2	1	2	3	1	2	3	1	1	3	1	2	3	2	2	4	1	1
4	4	2	4	4	2	2	4	2	1	3	1	3	3	1	3	3	1	2	3	0	0	2	1	1	4	0	0
5	4	2	2	4	3	3	4	2	3	2	1	2	3	2	2	3	2	2	2	0	1	1	0	1	4	0	1

	Experiment 2 (cont.) August 8–Sept. 3 Check Bird No.									Experiment 3 Sept. 12–Oct. 10 Check Bird No.							Sept. 12–Oct. 10 Check Bird No.					
	5448			5450			5334			5106			5405			5118			5145			5449			5173		
	S	B	F	S	B	F	S	B	F	S	B	F	S	B	F	S	B	F	S	B	F	S	B	F	S	B	F
1	3	1	2	3	1	1	2	1	1	3	2	0	3	3	1	3	2	1	3	0	2	3	1	1	3	1	2
2	3	0	2	3	1	1	3	1	2	3	2	1	3	3	1	3	2	1	3	1	2	3	1	1	3	1	1
3	3	1	2	2	1	2	3	1	0	3	2	1	3	3	1	3	3	1	3	1	2	3	2	2	4	1	1
4	3	1	1	2	0	1	2	0	1	3	1	1	2	2	0	3	3	1	[1]			3	2	2	4	1	1
5	3	0	1	2	0	1	2	0	1	3	1	1	3	2	0	3	1	0				3	3	1	3	2	1

	Experiment 4 Oct. 24–Nov. 21 Check Bird No.									Oct. 24–Nov. 21 Check Bird No.									Experiment 5 March 19–April 23 Check Bird No.								
	5110			5453			5130			5424			5157			5183			5627			5628			5658			5661		
	S	B	F	S	B	F	S	B	F	S	B	F	S	B	F	S	B	F	S	B	F	S	B	F	S	B	F	S	B	F
1	2	2	3	1	2	0	2	1	0	3	0	1	2	3	1	2	0	1	4	0	4	4	0	2	1	0	2	3	0	2
2	2	2	3	2	2	0	2	1	0	3	1	1	3	3	1	2	1	1	4	0	4	4	0	2	2	0	1	2	0	2
3	2	3	2	3	2	0	3	1	0	3	2	1	2	3	1	2	1	1	4	0	4	3	0	2	3	0	1	1	0	2
4	2	2	2	3	2	0	2	1	0	3	2	0	2	2	1	2	2	1	4	0	4	3	0	2	2	0	2	[2]	0	1
5	3	2	2	2	2	0	2	1	0	3	2	1	3	2	1	2	2	1	4	0	4	3	0	2	2	0	1	0	0	1

[1] Bird number 5145 died.
[2] Bird number 5661 got into pen treated with sulfur and became contaminated between fourth and fifth weeks.

Table 9.—Treatment of soil and use of treated shavings.

Insp. No.	Experiment 7 Apr. 7–May 12 Soil Treatment Under Wire Bird No. 86607 S	B	F	87098 S	B	F	Experiment 7 Apr. 7–May 12 Shavings Treated With Sulfur Bird No. 86656 S	B	F	36321 S	B	F
1	4	4	2	4	1	4	4	2	4	4	2	1
2	4	4	2	4	2	4	1	0	1	1	1	1
3	4	4	4	4	2	4	0	1	0	0	0	0
4	4	4	2	3	3	4	0	0	0	0	0	0
5	4	4	3	2	1	4	0	0	0	0	0	0
6	4	4	3	2	1	4	0	0	0	0	0	0

per 100 square feet and the house with 5 pounds of sulfur every 10 days. There was a decrease in lice after the first application. Fifteen birds were used in this test and 10 of these were found free of lice at the third weekly inspection. The other five had a very light infestation of one species of louse. Only 2 birds were infested at the fourth inspection. Approximately the same number was found to have a light infestation at each subsequent inspection.

Where birds are retained in a house and a dust bath is provided good lice control may be obtained by incorporating 10 per cent of dusting or commercial flour sulfur in the bath.

During 1942 M. W. Emmel (1942)[1] of the Florida Agricultural Experiment Station conducted laboratory and field experiments which corroborated the authors' data pertaining to internal submission and soil treatments.

SHAVINGS TREATED WITH SULFUR.—A combination inside and outside cage was used in this test. The floor of the inside cage was covered with fine sawdust. The sawdust was treated with a liberal quantity of dusting sulfur at the beginning of the experiment. The birds were observed to dust themselves thoroughly with the sulfur treated shavings. Sulfur particles were noted among their feathers. Results are given in table 9. The second week population count revealed a sharp reduction in lice populations of all species. The third week only a few body lice were present and subsequent inspections revealed complete freedom. There was some swelling noted about the heads of these birds.

SULFUR COMPOUNDS AND WETTABLE SULFUR.—The birds used in experiment 8 were retained in the experimental house and confined in small apartment cages. Bird number 5655 was dipped in a wettable sulfur bath after the first inspection. The dip consisted of 8 pounds of wettable sulfur in 100 pounds of water, or approximately 8 pounds of sulfur in 12 gallons of water. This is very concentrated. Bird number 5667 was dipped in solution containing 32° Baumé lime sulfur concentrate at the rate of 1 gallon to 60 gallons of water to which was added wettable sulfur at the rate of 1 pound in 60 gallons. Bird number 5651 was dipped in 32° Baumé concentrated lime sulfur dip which was made at the rate of 1 gallon of the concentrate in 60 gallons of water. Results are tabulated in table 10. The reader will note that there was practically a 100 per cent control immediately after treatment. In each instance there was complete body freedom from lice at the third population count. In each instance the bird was transferred after 21 days to an outside flock that was heavily infested with lice and

[1] Field Experiments in the Use of Sulfur to Control Lice, Etc. by M. W. Emmel. Bulletin 374, Florida Agricultural Experiment, Station, Gainesville, August 1942.

Table 10.—Experiment 8. Various treatments. March 6 to April 16.

Insp. No.	8% Wettable Sulfur Dip Bird No. 5655 S	B	F	Wettable and Lime Sulfur Dip Bird No. 5667 S	B	F	Lime Sulfur Dip Bird No. 5651 S	B	F	Check Bird No. 5654 S	B	F
1	4	0	4	4	0	4	4	0	4	4	0	1
2	1	0	0	1	0	0	0	0	0	4	0	1
3[1]	0	0	0	0	0	0	0	0	0	3	0	1
4	1	0	1	1	0	1	0	0	0	2	0	1
5	0	0	0	0	0	1	[2]Bird died			4	0	1
6	0	0	0	1	1	0				2	0	3

[1] Birds all placed in outside pen at this time with the infested flock and left for two days. They were then transferred back to test cages.
[2] Death not due to dip.

was permitted to remain there for 2 days and then returned to the apartment cages inside. The reassociation with infested birds usually brought about a reinfestation. In the case of bird number 5655 there was apparently a sufficient residue to bring about a control of this reinfestation as the body was again free of lice at

submission of sulfur. The tests proved that such treatment was ineffective. Tests involving the incorporation of sulfur in a balanced mash feed were made in which the sulfur constituted 5 to 10 per cent by weight. Such treatments gave only limited controls. The control was greatest in the neck region. Birds that were dusted with

Table 11.—Experiment 9. Various treatments. April 6 to May 12.

Insp. No.	8% Wettable Sulfur Dip Bird No. 86673 S	B	F	86595 S	B	F	Lime Sulfur Dip 1–60 Bird No. 86604 S	B	F	87168 S	B	F	Check Bird No. 54686 S	B	F	5670 S	B	F
1	4	2	3	4	4	2	4	4	1	4	2	4	4	3	3	4	0	3
2	1	0	0	0	0	1	0	0	0	0	0	0	4	1	3	4	0	4
3	0	0	0	0	0	1	1	0	0	0	0	0	4	1	4	4	0	4
4	0	0	0	0	0	0	0	0	0	0	0	0	4	1	4	4	1	4
5	0	0	0	0	0	0	0	0	0	0	0	0	4	1	4	4	0	4
6	0	0	0	0	0	0	0	0	0	0	0	0	4	0	4	4	1	4

the fifth and sixth inspections. Bird number 5667 retained the new infestation. Bird number 5651 died of causes other than lice or treatment.

In experiment No. 9 the birds were confined in portable coops under outdoor conditions. Birds 86,673 and 86,595 were dipped in a wettable sulfur solution containing 8 pounds of the sulfur in 100 gallons of water. Birds number 86,604 and 87,168 were dipped in a lime sulfur solution containing 32° Baumé lime sulfur at the rate of 1 gallon of lime sulfur in 60 gallons of water. All birds had heavy infestations of all three types of lice studied. It will be noted that there was practically a complete elimination of lice immediately following treatment and all birds were completely free at the fourth inspection. Results are recorded in table 11.

Subsequent tests by the senior author on several small farm flocks have indicated that a lime sulfur dip at the rate of 1 part of 32° Baumé lime sulfur in 60 to 100 parts of water will give a 100 per cent control of chicken lice. Likewise a wettable sulfur dip at the rate of 5 to 8 pounds of wettable sulfur in 100 gallons of water gave good control. Fifty to 75 birds were used in each test.

SUMMARY.—A series of tests were conducted to determine the efficacy of the treatment for chicken lice by the internal 5 and 10 per cent mash feed were freed of lice, indicating that a proper contamination would result in control. Field tests of sulfur-mash feeding did not indicate that this would be a logical method when used alone. Tests were conducted in which chickens were periodically dusted with dusting sulfur. Controls were excellent. Soil treatment tests were made in which dusting sulfur was added at the rate of 5 to 10 pounds per 100 square feet. Small and medium scale tests indicated that control would be partial or complete. A test was conducted in which the birds were suspended in a pen 2 inches above heavily sulfur treated soil. There was no control, indicating clearly that the control where soil treatment is involved is dependent upon contamination through the normal dusting activity of the birds. Sulfur treated sawdust gave control in a manner similar to the soil treatments. Experiments were conducted using wettable sulfur and 32° Baumé lime sulfur concentrate dips. Wettable sulfur at the rate of 5 to 8 pounds to 100 gallons and lime sulfur concentrate at one gallon in 60 to 100 gallons of water were very effective. They gave 100 per cent control in 1 to 2 weeks. Body residues were not permanent enough to protect the birds from reinfestation when they were exposed to heavily infested birds.—5-10-43.

Studies of Methyl Bromide, Chloropicrin, Certain Nitriles and Other Fumigants Against the Bedbug[1]

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The control of bedbugs *Cimex lectularius* L., is particularly important under wartime conditions, since places where numbers of people congregate such as soldiers' barracks and sailors' quarters are favorable for the development of infestations. The likelihood of such infestations in air-raid shelters in England was mentioned by Busvine (1941), and more recent reports (Great Britain Medical Research Council 1942) have confirmed this prediction. Although the bedbug does not seem to have been definitely incriminated as a disease carrier under natural conditions (Hegner *et al.* 1938), the work of Milzer (1942) suggests that it may be an important vector of lymphocytic choriomeningitis (Anonymous 1942).

Laboratory studies have been made of the fumigation efficiency of a number of chemicals, including acrylonitrile (Richardson & Casanges 1942b), 1,1-dichloro-1-nitroethane (O'Kane & Smith 1941), and certain chloroacetonitriles (Peters 1940), that have recently been found toxic to various insects. Methyl bromide, chloropicrin, hydrocyanic acid, carbon disulfide, and 15 other fumigants have also been tested. Approximately 150 fumigations have been made in glass flasks and in a steel cylinder, on approximately 15,000 eggs and 30,000 nymphs and adults of the bedbug. These experiments are discussed in this paper.

MATERIALS AND METHODS.—The bedbugs were reared in the laboratory by methods described by Woodbury & Barnhart (1939) and Campbell *et al.* (1941). The insects were kept at 77° F. and allowed to feed once a week on rabbit. Eggs up to 4 days old, first- to fifth-stage nymphs, and adults approximately 4 to 20 days old were used in the tests.

The chemicals tested are listed in table 1. In general they were of the best quality obtainable commercially, and some were of C. P. grade.

The fumigations were made by direct exposure of the insects to the gas either in a 12-liter glass flask by a method previously described (Richardson & Casanges 1942b) or in a 7.7-cubic-foot steel cylinder. Most of the chemicals, including liquid hydrocyanic acid, were measured under a hood with a micropipette to which was attached a hypodermic syringe lubricated with stopcock grease. Ethylene oxide and methyl bromide were measured with a gas burette in the flask tests, but the larger quantities needed in the steel cylinder were measured in a cooled, graduated glass cylinder.

In the flask tests the insects and eggs on a small piece of cardboard were placed in a shallow glass beaker and quickly lowered into the flask after the gas had been vaporized there. Preliminary tests indicated that it made little difference whether the insects were fumigated in the glass beaker, allowed to crawl directly over the floor of the flask, or placed in the flask and exposed to the lower pressure present during gas vaporization.

In the steel-cylinder tests the insects and eggs, on cardboard, were placed in an organdy-covered Petri dish and exposed directly to the fumigant, or the dish was wrapped in 6 to 8 layers of cotton batting to indicate penetrative efficiency in cotton-containing materials such as mattresses. The chemical was injected from a pipette onto a shallow pan at the top of the cylinder, where it vaporized. A small fan was run at very low speed for the first 10 minutes to distribute the gas. The slight increase in pressure due to vaporization was then relieved. With a number of the more toxic gases some final tests were made under loaded conditions by placing a barracks bag containing a 25-pound unit of clothing and blankets in the cylinder. The barracks bag contained 2 heavy woolen blankets (each weighing about 4 pounds), a heavy overcoat, a suit coat, trousers, a blouse, summer and winter underwear, socks, and shoes. This gave a load of approximately 3 pounds of clothes per cubic foot of space. A sample of bedbugs was wrapped in 8 to 10 layers of each

[1] Early publication accorded this paper because of its war emergency value.

[2] The writer acknowledges with thanks the assistance of Maurice Wehr during part of the investigations, and the provision of a colony of bedbugs by F. L. Campbell, of Ohio State University.

blanket. One blanket was exposed directly to the fumigant, and the other was packed in the center of the filled barracks bag. Another sample of bedbugs was wrapped in 6 to 8 layers of cotton batting and placed beside the first blanket.

All fumigations were made for 5 hours at 77° ± 0.9° F., atmospheric pressure and a relative humidity of from 50 to 95 per cent.

Usually about 100 eggs, 50 nymphs in the second to fifth instars, and 30 adults were used in each test. First instars were included in most of the earlier tests, but their use was discontinued because in general they were found to be less resistant than the older stages. After the fumigation the insects were kept in Petri dishes at near 77° F. The nymphs and adults were examined 1 and 6 days, and in some cases 10 and 20 days, after fumigation. The mortality observed on the sixth day was used in the final determinations, since most of the toxic action appeared to have taken place by that time. As a precaution, moribund insects present at that time were counted as alive although some of them may have died later. Examinations for egg hatching were made 15 days after treatment. Untreated control insects and eggs were checked at intervals during the work, but after 6 and 15 days, respectively, the mortality was generally negligible and no account was taken of it in calculating efficiency.

EFFICIENCY IN GLASS FLASKS.—Most of the chemicals were tested at three to six different concentrations, although some of the less toxic ones were given only one or two preliminary tests. From these results the approximate concentrations to give 95 to 100 per cent kill of the various stages were roughly determined. The 50 per cent, or median lethal, concentration of some of the chemicals was determined, but inasmuch as it cannot be used to forecast the concentration required for 65 to 100 per cent kill (Shepard 1934, Richardson & Casanges 1942a), the emphasis was placed on the latter concentration, which is of major importance in practical control. The data are summarized in table 1.

To most of the fumigants, but especially to ethylene oxide and ethyl formate, the eggs were more susceptible than the nymphs or adults.[1] On the other hand, the eggs were the most resistant to dichloroethyl ether, and in the preliminary tests to trichloroethylene (confirming work reported by Busvine 1941), methylallyl bromide, and 1-nitropropane. The older nymphs were the most resistant stage to most fumigants. The active stages were generally used between 4 and 8 days after feeding, as it was found, with chloropicrin, that recently fed insects were less resistant —similar to the findings of Mayer (1934), Busvine (1938), and Gough (1940) with some other fumigants.

Table 1.—Toxicity of various chemicals as fumigants against various stages of the bedbug. Five-hour exposures at 77° F. (25° C.) in 12-liter glass flasks. Chemicals listed in approximate order of toxicity to the older nymphs.

CHEMICAL	APPROXIMATE CONCENTRATION TO GIVE 95 TO 100 PER CENT KILL		
	Older nymphs	Adults	Eggs
	Mg. per liter	*Mg. per liter*	*Mg. per liter*
Hydrocyanic acid, HCN	0.4	<0.4	<0.4
Acrylonitrile, CH_2:CHCN	3–4	<2.5	2
Chloracetonitrile, CH_2ClCN	3–4	<3	<3
Chloropicrin, CCl_3NO_2	5–6	3	<2.75
α,β-Dichloroethyl ether, $C_2H_4OCHClCH_2Cl$	5–6	5–6	>6
Acrylonitrile-carbon tetrachloride mixture (1:1 by vol.)[1,2]	7.5	6–7.5	6
1,1-Dichloro-1-nitroethane, $CH_3CCl_2NO_2$	8	<8	<8
Methyl bromide, CH_3Br	9	<7	<7
Dichloroacetonitrile, $CHCl_2CN$	10	<8	<8
Trichloroacetonitrile, CCl_3CN	11	8	<8
Ethylene oxide, $(CH_2)_2O$	14	6–10	<2
1-Nitropropane, $C_2H_5CH_2NO_2$[3]	—	—	—
o-Dichlorobenzene, $C_6H_4Cl_2$[3]	—	—	—
Methylallyl chloride (3-chloro-2-methylpropene-1), CH_2:$C(CH_3)CH_2Cl$	25–30	<25	<25
Ethyl formate, $HCOOC_2H_5$	30	25–30	<25
1-Nitrobutane, $C_3H_7CH_2NO_2$[3]	—	—	—
Nitroethane, $CH_3CH_2NO_2$[3]	—	—	—
Ethylene oxide-ethylene dichloride mixture (1:3 by vol.)[1]	35	25–30	<25
Tetrachloroethane-trichloroethylene mixture (1:1 by vol.)[3,4]	—	—	—
sym-Tetrachloroethane, $CHCl_2CHCl_2$	35	35	25
Methylallyl bromide (3-bromo-2-methylpropene-1) CH_2:$C(CH_3)CH_2Br$[3]	—	—	—
Carbon disulfide, CS_2	37.5	<30	30
Ethylene dichloride, CH_2ClCH_2Cl	>50	>50	>50
Ethylene dichloride-carbon tetrachloride mixture (3:1 by vol.)[1]	>50	>50	>50
Carbon tetrachloride, CCl_4	>50	>50	>50
Trichloroethylene, $CHCl$:CCl_2	>50	>50	>50

[1] Figures given are for the combined weight of both chemicals.
[2] On the basis of acrylonitrile only, the figures would be 2.5, 2.5–3, and 2 mg. per liter.
[3] Subjected to preliminary tests only.
[4] Slightly more toxic than tetrachloroethane on the basis of tetrachloroethane content only.

Hydrocyanic acid was the most toxic gas, the results being similar to those of Gunderson & Strand (1939) and others.

[1] The fact that the young, and probably more resistant, eggs were used in the tests should also be considered. Gough (1940) found young eggs to be more resistant than older eggs to sulfur dioxide fumigation, and this probably holds true for most fumigants.

Acrylonitrile, which had previously been found very toxic to the confused flour beetle (*Tribolium confusum* Duv.) (Richardson & Casanges 1942b), was the next most toxic chemical. It had a slightly delayed action against the bedbug similar to that noted against the flour beetle. That is, bedbugs exposed to a killing dosage might appear to be affected slightly or not at all at the end of the fumigation, but all would be dead by the next day. Acrylonitrile is a colorless liquid with a boiling point of 78°–79° C., near that of ethylene dichloride, and is used in the synthesis of artificial rubber. It has a disadvantage in being somewhat flammable, but this can be overcome by mixing it with an equal volume of carbon tetrachloride. The addition of carbon tetrachloride also appeared to increase the toxicity, although this compound apparently was nontoxic at these concentrations. For example, in six paired tests with bedbug nymphs at various concentrations, but with each pair having the same dosage of acrylonitrile, the percentage mortalities were as follows:

Acrylonitrile	Acrylonitrile-carbon tetrachloride
0	40
10	37
36	68
58	98
58	88
76	100

Inasmuch as carbon tetrachloride probably acts also as a carrier to give gas distribution, as it does with other fumigants (Farrar & Flint 1942), its addition has several advantages.

The action of acrylonitrile on warm-blooded animals, according to Dudley & Neal (1942), is like that of a typical nitrile. Cleavage of the molecule probably occurs to produce hydrogen cyanide. They found dogs to be much more susceptible than guinea pigs, the minimum fatal dosage in a 4-hour exposure being near 0.24 mg. per liter for the former and 1.38 mg. for the latter. Dudley, Sweeney, & Miller (1942) obtained no definite evidence of cumulative action in repeated exposures to low concentrations (50 to 150 p.p.m.). In an addendum to their paper Neal & Van Oettinger state that acrylonitrile and hydrogen cyanide seem to be of a very similar order of toxicity to warm-blooded animals on the basis of cyanide content. Until further information is gathered, they propose a maximum permissible concentration of 20 p.p.m. (0.043 mg. per liter) for acrylonitrile in an 8-hour exposure. This compares with the present accepted figure for hydrocyanic acid of 20 p.p.m., or 0.02 mg. per liter.

Chloroacetonitrile and the di- and trichloroacetonitrile are sneeze-type, nonflammable gases, recommended in Germany (Peters 1940) for control of bedbugs and other insects. Although chloroacetonitrile appeared to be the most toxic and was similar in toxicity to acrylonitrile, as was found with the flour beetle (Richardson & Casanges 1942), it had the disadvantage of being slow to vaporize. Trichloroacetonitrile, the least toxic of the three, appeared to have some delayed killing action between the sixth and tenth days after fumigation. Busbey *et al.* (1942) have recently found trichloroacetonitrile, to be more toxic than methyl bromide to the California red scale.

Chloropicrin, which showed high toxicity, has been reported as being much less toxic to the eggs than to the nymphs or adults (Bertrand, *et al.* 1919, Gunderson & Strand 1939, Peters 1939). The present data confirm the toxicity figures of Gunderson & Strand for the nymphs and adults, as well as being near though slightly higher than those of Sherrard (1942), but they show the eggs to be much more susceptible. In paired tests at various dosages the mortalities for older nymphs were 40, 45, 51, 55, 58, 60, and 65 per cent compared with 100 per cent kill of the eggs in all the tests except one, where it was 94. The higher toxicity to the eggs was also noted in other tests. Against the nymphs and adults chloropicrin appeared to have some delayed killing action from the sixth to tenth day after fumigation.

α,β-Dichloroethyl ether was among the more toxic chemicals, but it vaporized very slowly. It may be worth detailed study in some phase of bedbug control, such as in spraying vacant houses or houses that are to be demolished.

Ethylene oxide was not found so toxic to nymphs and adults as reported by Gunderson & Strand (1939), but the toxicity figures were near those of Busvine (1938). The concentration needed for killing the eggs was only about one-seventh, or less, that needed to kill the older nymphs, these results being similar to

those of Mayer (1934) and Busvine (1938) The addition of ethylene dichloride to ethylene oxide in a proprietary mixture appeared to increase its efficiency slightly when compared on the basis of equal dosages of ethylene oxide. Ethylene dichloride alone appeared to have little if any toxic effect at these concentrations.

1-Nitropropane seemed to be about as effective against the bedbug as against the flour beetle (Richardson *et al.* 1943). Preliminary tests with 1-nitrobutane and nitroethane indicated them to be less toxic in that order, the results differing from those with the flour beetle.

o-Dichlorobenzene appeared to be similar in toxicity to 1-nitro-propane. Bedbugs fumigated with o-dichlorobenzene became very active and appeared to be much irritated. It is important to note, however, in a report of an English committee on bedbug infestation (Cameron 1942), that o-dichlorobenzene was rejected as a bedbug fumigant or spray because of its danger from the health standpoint.

Methylallyl chloride, which has been recommended as a fumigant in Europe (Briejèr 1938, 1939), was among the less toxic compounds. The closely related compound methylallyl bromide was less toxic, contrary to results with the flour beetle

Tetrachloroethane was among the less toxic materials, although more toxic than the closely related compound ethylene dichloride. It vaporized very slowly at room temperature. A mixture of tetrachloroethane and trichloroethylene has been patented by Balázs (1939) for use against bedbugs. In the present work a 1:1 mixture (by vol.) gave 98, 100, and 100 per cent kill of nymphs, adults, and eggs, respectively, compared with 71, 100, and 100 per cent given by tetrachloroethane tested at the same tetrachloroethane dosage (30 mg. per liter). Trichloroethylene alone at about the same dosage had little if any killing action, but it did have an unusual anesthetic action, for all the insects appeared paralyzed at the end of fumigation but were completely recovered by the next day.

Ethylene dichloride was relatively low in toxicity. Preliminary tests indicated that it had some delayed killing action between the sixth and twentieth days after fumigation, but by no means to the extent it had in previous work against the flour beetle. The addition of carbon tetrachloride did not appear to increase its efficiency. Carbon tetrachloride alone was also among the least toxic chemicals tested.

FUMIGATION EFFICIENCY IN AN UNLOADED STEEL CYLINDER.—Most of the chemicals found to have the highest toxicity in the flask tests were tested three to five times in the unloaded steel cylinder together with two organdy-covered Petri dishes containing insects, one being wrapped in 6 to 8 layers of cotton batting. In general, the gases tested had no difficulty in penetrating the cotton. For example, in five paired tests with various dosages of acrylonitrile and four with chloropicrin the percentage mortalities of the older nymphs were as follows:

Acrylonitrile		Chloropicrin	
Nymphs exposed directly	Nymphs wrapped in cotton	Nymphs exposed directly	Nymphs wrapped in cotton
100	99	97	98
100	100	93	84
97	99	60	66
94	98	45	58
13	25		

Similar results were obtained with chloroacetonitrile, methyl bromide, 1,1-dichloro-1-nitroethane, di- and tri-chloroacetonitrile, ethylene oxide and its mixture with ethylene dichloride, and ethyl formate.

In the case of acrylonitrile, chloropicrin, 1,1-dichloro-1-nitroethane, and methyl bromide, the concentrations required for 95 to 100 per cent kill in the unloaded steel cylinder were approximately the same as those found necessary in the glass flasks. With hydrocyanic acid, chloroacetonitrile, di- and tri-chloroacetonitrile, ethylene oxide-ethylene dichloride mixture, and ethyl formate, however, somewhat higher concentrations were required in the steel cylinder. The reason for this is not known at this time.

FUMIGATION EFFICIENCY IN A LOADED STEEL CYLINDER.—Some of the more toxic fumigants were given preliminary tests in the heavily loaded steel cylinder (3 pounds of clothing per cubic foot of space) to determine the penetrative powers into cotton batting and woolen blankets exposed directly to the gas or packed in the center of a bag of clothing. A uniform dosage of 20 mg. per liter (20 ounces per

1,000 cubic feet) was used. The results are shown in table 2.

The mortality figures indicate that the woolen blanket placed in the center of a bag of clothes furnished the most difficult test of penetration.

These and other tests at dosages of 16 and 18 mg. per liter indicate methyl bromide and chloropicrin to be the most efficient chemicals under the heavily loaded test conditions. They were used at only about 2 and 3 times, respectively, the dosages required to kill in an empty flask or cylinder. On the other hand, property. Its vapor is very heavy (sp. gr. 4.95, air = 1).

Ethylene oxide was near chloroacetonitrile in efficiency against nymphs.

In a further test at 18 mg. per liter methyl bromide and chloropicrin seemed to be very close in efficiency. The mortalities of older nymphs caused by methyl bromide were 98.6, 94.7, and 100 per cent in cotton, blanket, and blanket in clothes, respectively, compared with 100, 100, and 93 per cent for chloropicrin. Both gases are practically nonflammable. Chloropicrin has strong warning properties and

Table 2.—Efficiency of several fumigants against bedbugs wrapped in various materials to test for penetrative powers under heavily loaded conditions. Dosage, 20 mg. per liter. Five-hour exposures at 77° F. and normal atmospheric pressure.

Chemical	Percentage Mortality of Bedbugs Wrapped in—								
	Botton Batting			Woolen Blanket			Woolen Blanket in Barracks Bag		
	Older nymphs	Adults	Eggs	Older nymphs	Adults	Eggs	Older nymphs	Adults	Eggs
Methyl bromide	100	100	100	100	100	100	100	100	100
Chloropicrin	100	100	100	100	100	100	100	100	100
Hydrocyanic acid	100	100	100	100	100	100	61.3	96.7	100
Acrylonitrile-carbon tetrachloride mixture (1:1 by vol.)	100	100	100	92.8	100	100	20	25	20.5
Trichloroacetonitrile	94.5	97.5	96.8	75	100	100	64	89.4	98.3
1,1-Dichloro-1-nitroethane	76.6	97.5	78	66.7	97.9	84.3	31.5	67.4	54.3
Ethylene oxide	37.7	—	—	17.8	—	—	24.2	—	—
Chloroacetonitrile	30.6	75	—	1.9	7.3	—	14.8	14	—

hydrocyanic acid at 20 to 30 times the killing dosage gave irregular results and appeared slightly less efficient. Acrylonitrile-carbon tetrachloride mixture at a dosage to give 20 mg. of acrylonitrile per liter, or about 8 to 10 times the killing dosage, was next in efficiency, followed closely by trichloroacetonitrile and 1,1-dichloro-1-nitroethane.

Trichloroacetonitrile at less than twice its killing dosage gave much higher efficiency than chloroacetonitrile used at 5 to 6 times its killing dosage. It is a colorless liquid with a boiling point of 85° C. Its gas is nonflammable. It aerated rapidly from clothing at the temperature tested and might well be considered for further study. Peters (1940) states that it has about the same toxicity to warm-blooded animals as ethylene oxide and methylallyl chloride, but there is little danger of poisoning because of its great warning

appeared to have little if any effect on fumigated clothes, but its relatively low vapor pressure might restrict its efficiency at lower temperatures. Methyl bromide has a high vapor pressure and it appeared to have little effect on the clothes or leather shoes under the test conditions maintained.

SUMMARY.—Twenty-six chemicals or mixtures were tested as fumigants against the eggs, nymphs, and adults of the bedbug (*Cimex lectularius* L.) in 12-liter glass flasks; some of the more toxic chemicals were also tested in a 7.7-cubic-foot steel cylinder. Approximately 150 five-hour fumigations were made at 77° ± 0.9° F. with approximately 15,000 eggs and 30,000 nymphs and adults.

In the fumigations in empty glass flasks hydrocyanic acid was the most toxic gas. It was followed by acrylonitrile and its mixture with carbon tetrachloride, chloro-

acetonitrile, chloropicrin, and dichloroethyl ether. Slightly less toxic in the descending order were 1,1-dichloro-1-nitroethane, methyl bromide, di- and trichloroacetonitrile, and ethylene oxide.

The addition of carbon tetrachloride to acrylonitrile (1:1 by vol.) to produce a nonflammable mixture also gave increased efficiency

Chloropicrin was more effective against the eggs than against the older nymphs and adults.

The second to fifth instars were generally the most resitant and the eggs the least resistant. This relationship varied with some chemicals, the egg being most resistant to dichloroethyl ether and trichloroethylene. The egg was much more susceptible to ethylene oxide. Trichloroethylene had an anaesthetic action against the active stages.

In tests with the more toxic materials in an unloaded steel cylinder the efficiency was just as great against insects protected by cotton batting as against those exposed directly to the gas.

In a loaded steel cylinder methyl bromide and chloropicrin were the most efficient gases when used at a dosage of 16 to 20 mg. per liter (16 to 20 ounces per 1000 cubic feet) against bedbugs wrapped in cotton batting or in woolen blankets exposed directly to the gas, or packed in the center of a 25-pound barracks bag (3 pounds of clothing per cubic foot of cylinder space). Hydrocyanic acid appeared slightly less effective, followed by acrylonitrile-carbon tetrachloride mixture, trichloroacetonitrile, 1,1-dichloro-1-nitroethane, ethylene oxide, and chloroacetonitrile, listed in the approximate order of descending efficiency.—4-5-43.

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Linseed Oil Soap—A New Lure for the Melon Fly

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Fruitfly lures are frequently used in scouting for flies in the field or as a means of following the progress of field investigations. Consequently one of the projects of the Bureau of Entomology and Plant Quarantine includes a search for more powerful lures. This paper records the discovery of the melon fly lure linseed oil soap, experiments to identify the attractive component of the new lure, and some attempts to control the melon fly (*Dacus cucurbitae* (Coq.)) with the lure.

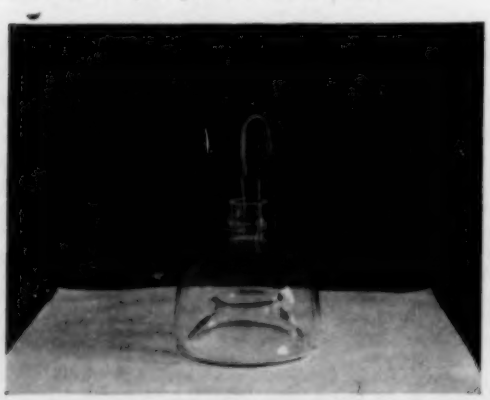

FIG. 1.—Glass trap used for testing lures for the melon fly. Photograph by R. H. Marlowe.

EXPERIMENTAL TRAPPING TECHNIQUE.—To compare the response of the melon fly to various materials in the field, Ripley and Hepburn's "method 2" was employed.[1] This method is now standard in the Bureau's fruitfly lure investigations, and is usually referred to as the "reversed-pairs method." It has been extensively investigated statistically, first by Donald F. Starr at the Mexico City laboratory and more recently by Kam Hu Lau and the writer at the Honolulu laboratory. As the name implies, the method consists in pairing control and test traps (usually 4 feet apart) with reversal of position during a second exposure. These traps are illustrated in figure 1.

Some uniformity data by this method are recorded in table 1. In each of these tests 30 pairs of traps were baited with the same lure. One member of each pair was designated the control trap and the other the test trap. The ratios obtained include a maximum error of 16 per cent. The

Table 1.—Uniformity data obtained by the reversed-pairs method of experimental trapping.

TEST NO.	NUMBER OF FLIES CAUGHT		RATIO CONTROL/TEST
	Control traps	Test traps	
1	2,023	2,256	0.90
2	2,267	2,541	0.89
3	2,157	2,377	0.91
4	1,884	2,242	0.84
5	1,618	1,890	0.86
6	1,975	2,016	0.98
7	1,865	1,852	1.01
8	1,592	1,717	0.93
9	1,326	1,365	0.97
10	2,150	2,096	1.03
11	1,877	1,961	0.96
12	1,611	1,609	1.00
13	1,713	1,851	0.93
14	1,447	1,499	0.97
15	1,312	1,226	1.07

[1] Ripley, L. B., and Hepburn, G. A. Studies on reactions of the Natal fruit-fly to fermenting baits. So. Africa Dept. Agr. and Forestry, Ent. Mem. 6: 19–53, illus. 1929.

minimum number of traps necessary to insure accurate results is a debatable question. In the present work 15, 20, or 30 pairs, usually 20, were employed.

THE DISCOVERY.—Because searching for insect lures is still a needle-in-the-haystack proposition, the following account of the discovery of linseed oil soap as a strong melon fly lure may be of interest.

Since the melon fly was known to concentrate on the blossoms of a common orchid, *Denbrobium superbum*, attention was focused on this orchid. In the initial experiments, in which the response of caged flies to blossoms and to extracts of blossoms was observed, good response was obtained, but it was confined to male flies only. Experiments in the field followed.

In the first experiments orchid blossoms were suspended in traps over 0.05 per cent[1] linseed oil soap solution and run against traps containing a protein lure,[2] which in these experiments consisted of 40 grams of casein, 15 grams of sodium hydroxide, and 1 liter of water. The soap was added to increase the wetting capacity of the water in the orchid traps so that captured flies would drown more readily. The results, which are shown in table 2, suggested the presence of a powerful lure for male flies in the orchid blossoms, agreeing in this respect with the laboratory experiments, but they also indicated an attraction for female flies in the orchid traps.

Table 2.—Casein lure vs. orchid blossoms suspended in traps over 0.05 per cent linseed oil soap solution.

Lure	Number of Flies Captured		Sex Ratio Males/Females
	Males	Females	
Casein	646	603	1.07
Orchard blossoms	1,571	257	6.11

In a second experiment an alcoholic extract of orchid blossoms suspended over 0.2 per cent linseed oil soap solution was run against casein (Table 3).

These results raised the question, Why did the extract attract a larger proportion of females than the blossoms? In the extract experiment the oil concentration was four times as great as in the blossom experiment. Could this be the reason for the difference in results? An experiment comparing casein with 0.2 per cent linseed oil soap solution confirmed these suspicions (Table 4).

Table 3.—Casein lure vs. alcohol extract of orchid blossoms suspended in traps over 0.2 per cent linseed oil soap solution.

Lure	Number of Flies Captured		Sex Ratio Males/Females
	Males	Females	
Casein	207	242	0.86
Extract of blossoms[1]	976	760	1.28

[1] The alcoholic extract was prepared by K. H. Lau.

Table 4.—Casein vs. 0.2 per cent linseed oil soap solution.

Lure	Number of Flies Captured		Sex Ratio Males/Females
	Males	Females	
Casein	153	178	0.86
0.2 per cent linseed oil soap	936	1,292	0.72

Thus ended the observations leading to the discovery of linseed oil soap as a melon fly lure.

In subsequent tests with alcohol extracts of orchid blossoms (Table 5), the extracts attracted many more males than females, and extracts from fresh and air-dried blossoms were about equally attractive to the males.

Table 5.—Alcohol extract of fresh orchid blossoms vs. alcohol extract of air-dried orchid blossoms.

Test No.	Source of Extract	Number of Flies Captured	
		Males	Females
1	Fresh blossoms	398	19
	Air-dried blossoms	329	104
2	Fresh blossoms	535	2
	Air-dried blossoms	539	16

[1] The indicated strength refers to the percentage of linseed oil used in making the soap solution.

[2] McPhail, M. Protein lures for fruitflies. JOUR. ECON. ENT. 32: 758–61. 1939.

ATTRACTIVENESS OF OTHER SOAPS.—Some of the more common soaps were tested individually against linseed oil soap as a control. The oil concentration used in making these soaps, including the control, was 0.2 per cent, except the stearic acid, which was 0.5 per cent, and the whale oil soap, which was a proprietary product of unknown strength. All the soaps were prepared by the writer except the whale oil soap. Potassium hydroxide was the saponification agent used.

Table 6.—Linseed oil soap vs. soaps made from other oils.

OIL	NUMBER OF FLIES CAPTURED	
	Control (linseed oil soap)	Test
Cottonseed oil	4,593	1,783
Corn oil	2,082	526
Coconut oil	1,778	24
Olive oil	3,253	61
Tung oil	1,034	18
Whale oil	1,624	35
Bitter melon seed oil	1,341	40
Stearic acid	1,824	195
Boiled linseed oil	820	94

These tests (Table 6) show that linseed oil soap was outstanding in attractiveness. Only two of the test soaps, those made from cottonseed oil and corn oil, attracted flies, the catch in the other traps being credited to trapping error. Soap made with boiled linseed oil was not attractive. Linseed oil soap smells like freshly cut cucumber, a severely attacked host of the melon fly, but soap made of oil from the seed of bitter melon, another severely attacked host, was not attractive.

EXPERIMENTS TO IDENTIFY THE ATTRACTIVE COMPONENT OF LINSEED OIL SOAP.—Linseed oil is a mixture largely of glycerides of fatty acids. Holde[1] lists the main componets of the oil as follows: "0.5 to 1.5 per cent of unsaponifiable; 8 to 9 per cent satur. acids (myristic, palmitic, stearic, arachidic), 15 to 20 per cent oleic, 25 to 35 per cent linoleic, 35 to 45 per cent linolenic acids; 4 to 5 per cent glycerine." It appears, then, that the attractant is one of three things—a component of the unsaponifiable portion of the oil, a fatty acid, or glycerol (glycerine). Glycerol can be eliminated immediately because it is present, unless removed, in all soaps prepared from oils or fats, and, as was shown in table 6, not all soaps are attractive.

When linseed oil was extracted with several volumes of alcohol, it was observed that the odor typical of the oil could be concentrated in the alcohol extract. A test to determine whether the attractive component of the oil could be concentrated in the alcohol extract was then made by comparing soap prepared from the extract of oil with soap prepared from the extracted oil. The catch was 468 flies in the extract soap and 1,105 in the extracted-oil soap. The extraction procedure was therefore abandoned.

Tests were next made with soaps prepared from the fatty acids of linseed oil. To obtain the fatty acids two methods were used. The first was to acidify the linseed oil soap solution and then extract it with ether. The second and better method, because it yielded purer acids, was to add a water solution of lead acetate to the nearly neutral linseed oil soap solution, collect and dissolve the precipitated lead salts in dilute hydrochloric acid, and then extract the solution with ether. These fatty acids were then saponified and tested against linseed oil soap. Table 7 shows that the fatty acid soaps were highly attractive, catching almost as many flies as the linseed oil soap.

Table 7.—Linseed oil soap vs. soaps prepared from fatty acids of linseed oil.

METHOD OF SEPARATING FATTY ACID	CONCENTRATION OF OIL OR FATTY ACID, PER CENT	NUMBER OF FLIES CAPTURED	
		Control (linseed oil soap)	Test
First	0.2	1,495	1,293
Second	.1	822	739
Second	.2	1,327	827

There followed tests with soaps made from some of the fatty acids known to be present in linseed oil—oleic, palmitic, and linoleic. The acids were converted to soaps and run individually against linseed oil soap. These acid soaps were not attractive, the catch being well within the trapping error (Table 8).

[1] Holde, D. The examination of hydrocarbon oils and of saponifiable fats and waxes. Ed. 2, translated by Edward Mueller, 572 pp., illus. New York and London. 1922.

Table 8.—Linseed oil soap vs. soaps prepared from fatty acids known to occur in linseed oil.

Fatty Acid	Number of Flies Captured	
	Control (linseed oil soap)	Test
Oleic	1,220	87
Linoleic	1,125	101
Palmitic	3,850	154

EXPERIMENTS TO CONTROL THE MELON FLY BY TRAPPING WITH LINSEED OIL SOAP.—A study was next made of performance in two intensively trapped ¼-acre bitter melon patches. The traps were evenly distributed in these patches and were operated continuously for several weeks except for a short interruption at the end of each exposure period, when they were examined and rebaited with fresh lure. The results are summarized in table 9.

Table 9.—Trap performance in two intensively trapped patches of bitter melons, 1939 and 1940.

Year	Number of Traps	Exposure Period	Number of Flies Captured	
			Total	Per trap per day
1939	136	Oct. 3–6	1,318	3.23
		6–10	1,835	3.37
		10–14	1,448	2.66
		14–18	2,551	4.69
		18–21	925	2.27
		21–25	1,606	2.96
		25–28	1,143	2.80
		28–Nov. 1	927	1.70
1940	75	May 8–10	2,830	18.9
		10–14	2,926	9.8
		14–17	2,202	9.8
		17–20	1,434	6.4
		20–23	1,779	7.9
		23–27	2,616	8.7
		27–31	2,324	7.7
		31–June 3	2,231	9.9

The traps in these patches, however, afforded little protection to the melons. Table 10 shows the number of flies recovered from bitter melons that were exposed at random in the patches for short periods, usually 2 days. The severity of the infestations may be surmised when it is realized that 2 days is not more than one-fifth of the time necessary for a bitter melon to mature.

The reason for the failure of traps in these experiments can be summed up in one word, "reinfestation." The trend in the trap data (Table 9) shows that there was little reduction in the fly population in either patch except during the first period in 1940; flies seemed to be reappearing in the patches as fast as they were being removed. In the 1939 patch reinfestation was largely from without, because the owner bagged all young melons as soon as they appeared, thus preventing the fly from reproducing. In 1940 bagging was not practiced and there was consequent reinfestation from within the patch as well as from without.

Table 10.—Infestation of melons in two intensively trapped patches of bitter melon, 1939 and 1940.

Year	Exposure Period	Melons Exposed	Flies Recovered	Melons Free of Flies
1939	Oct. 16–21	200	[a]	0
1940	May 17–19	40	6,597	0
	25–27	20	7,419	0
	27–29	20	5,973	0

[a] Melons eaten up, many of the larvae had emerged by Oct. 21.

SUMMARY.—In the course of investigations on the response of the melon fly (*Dacus cucurbitae* (Coq.)) to orchid blossoms, the inclusion of linseed oil soap in the traps to soften the water so that captured flies would drown more readily led to the discovery that linseed oil soap is a strong melon fly lure.

Tests comparing linseed oil soap with other common soaps showed that linseed oil soap was the strongest lure, but that cottonseed oil soap and corn oil soap were attractive.

Investigations suggested that the attractive component of linseed oil soap might be a fatty acid.

Attempts to protect bitter melons in the field from fly injury by trapping with linseed oil soap were not successful because of reinfestation.—4-11-43.

Lieut. Col. H. C. Mason, Infantry, is now stationed somewhere in England. He was formerly Associate Entomologist of the Bureau of Entomology and Plant Quarantine stationed at the Columbus, O. laboratory.

Chemotropic Tests of Materials Added to Standard Codling Moth Bait

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The results of chemotropic tests with adult codling moths, *Carpocapsa pomonella* (L.), show that large numbers can be attracted by fermenting baits (Newton, 1924; Yetter 1924; Yothers 1926). With the idea of developing measures supplementary to insecticidal control, studies of baits and bait materials were made at Yakima, Wash., during the period from 1933 to 1939. It is the purpose of this paper to record some preliminary results, particularly with molasses baits, which may be of value to other workers in further studies of the chemotropism of the codling moth.

Method and Technique.—The materials were tested in the field by a method similar to that used by the author in conducting chemotropic studies with the Japanese beetle (Van Leeuwen & Metzger 1930). The standard bait and a test bait were set out in an apple tree a few inches apart. This was accomplished by suspending them in stew pans at the ends of cross arms nailed to a board 3.5 inches wide, 0.75 inch thick, and long enough to reach the upper third of the tree. The standard bait consisted of a 10 per cent solution of molasses, and 1 cake of yeast to each 10 gallons. The test bait was the same as the standard with the addition of the chemical under test placed in an evaporation cup similar to that used by Peterson (1926). Each test was replicated from two to four times.

With this system the only difference in the two baits was the material under test; therefore, any wide difference in numbers of moths captured was certain to be due to this material. The baits were examined every other day, at which time water was added to replenish that lost by evaporation. If the vial was empty or nearly so, it was refilled with the test material. The method has one disadvantage—that the amount of material evaporated from the vial may in some cases be too small to affect the moth.

To determine the reliability of results obtained by this method, several tests were made during different periods of the 1933 season with two pans of standard bait replicated four times. The results are given in table 1. The difference ranged from 2.3 to 29.9 per cent. A part of this variation was due, no doubt, to the difference in the position of the baits in the tree, although they were within a few inches of each other. It is practically impossible to place two baits under exactly the same conditions.

Materials Tested.—The test materials were selected from a wide range of organic and inorganic compounds. Several of the chemicals had been reported as present in the apple, and many of the others had been tested against the Japanese beetle, *Popillia japonica* Newm., or the oriental fruit moth, *Grapholitha molesta* (Busck).

The results of the tests as given in table 2 indicate that more than half of the materials were attractive. These results, however, apply only to the tests herein described, and under other conditions different evaluations might be obtained.

Table 1.—Number of codling moths caught in pans set out in pairs, both pans containing the standard bait.

Period of Observation	Number of Moths Caught		Per Cent Difference (Based on the Smaller Record for Each Pair)
	Left-hand bait	Right-hand bait	
May 9–28	267	280	4.9
May 19–28	147	125	17.6
June 11–18	36	37	2.8
June 18–July 5	295	351	19.0
June 23–July 3	155	163	5.2
June 29–July 10	76	67	13.4
July 3–13	70	85	21.4
July 21–Aug. 3	287	296	3.1
July 24–Aug. 13	352	271	29.9
July 27–Aug. 16	291	269	8.2
Aug. 4–17	216	256	18.5
Aug. 14–Sept. 17	228	241	5.7
Aug. 22–Sept. 17	529	541	2.3
Aug. 28–Sept. 8	153	158	3.3
Sept. 11–Oct. 1	53	59	11.3

[1] This work was done under the supervision of E. J. Newcomer. Robert Every and Eldon Vredenburg conducted the field work and R. C. Roark grouped the materials as listed.

Table 2.—Effect of adding various materials to the standard bait on its attractiveness to the codling moth.

Compound	Number of Moths Caught		Percentage Catch Compared with Standard
	Standard bait	Test bait	
Alcohols			
Diacetone alcohol	139	179	+28.8
Amyl alcohol	58	85	+46.6
Benzyl alcohol	407	431	+ 5.9
Heptyl alcohol	463	185	−60.0
Isoamyl alcohol	290	266	− 8.3
Isobutyl alcohol	107	86	−19.6
Trimethylene glycol	75	79	+ 5.3
Esters			
Amyl acetate	77	100	+29.9
Isoamyl acetate	24	17	+29.2
Amyl benzoate	365	383	+ 4.9
n-Amyl *n*-butyrate	395	255	−35.4
Isoamyl caproate	506	604	+19.4
Isoamyl caprylate	306	383	+25.2
Isoamyl formate	52	29	−44.2
Amyl valerate	77	52	−32.5
Benzyl acetate	398	213	− 46.5
Benzyl benzoate	233	187	− 19.7
Benzyl butyrate	101	57	− 43.6
Benzyl cinnamate	404	511	+ 26.5
Benzyl phenyl acetate	39	26	− 33.3
Butyl acetate	278	253	− 9.0
Isobutyl acetate	266	224	− 15.8
Isobutyl benzoate	213	228	+ 7.0
Isobutyl butyrate	133	132	− 0.8
Butyl cinnamate	226	153	− 32.3
Butyl nitrate	836	557	− 33.4
Isobutyl phenyl acetate	448	737	+ 64.5
Butyl phthalate	599	452	− 24.5
Cinnamyl acetate	192	164	− 14.6
Ethyl acetate	537	525	− 2.2
Ethyl benzoate	51	63	+ 23.5
Ethyl caproate	319	213	− 33.2
Ethyl chloroacetate	159	162	+ 1.9
Ethyl cinnamate	298	254	− 14.8
Ethylene glycol diacetate	80	64	− 20.0
Ethyl propionate	472	434	− 8.1
Ethyl sulfate	102	141	+ 38.2
Guaiacol carbonate	64	81	+ 26.6
Methyl acetate	486	504	+ 3.7
Methyl benzoate	24	29	+ 2.1
Methyl-*n*-butyrate	66	90	+ 36.4
Methylphenyl carbinyl acetate	205	255	+ 24.4
Phenyl ethyl acetate	125	294	+135.2
Phenyl ethyl formate	355	601	+ 69.3
Phenyl ethyl propionate	136	187	+ 37.5
Aldehydes and ketones			
Acetaldehyde	120	191	+ 59.2
Acetophenone	76	67	− 11.8
Benzaldehyde	312	386	+ 23.7
Benzophenone	37	48	+ 29.7
Butyraldehyde	32	17	− 46.9
Cinnamaldehyde	51	58	+ 13.7
Formaldehyde	94	81	− 18.3
Heptaldehyde	419	282	− 32.7
Methyl-*p*-tolyl ketone	300	195	− 35.0
Paraldehyde	149	219	+ 47.0
Pelargonal	441	442	+ 0.2
Phenylacetaldehyde	330	245	− 25.8
Propionaldehyde	141	146	+ 3.5
Amines and amides			
Acetamide	101	126	+ 24.8
Aniline	195	202	+ 3.6
Aniline acetate	134	142	+ 6.0
Aniline hydrochloride	76	70	− 7.9
Dimethylaniline	257	356	+ 38.5
Diphenylamine	41	60	+ 46.3
Diphenylguanidine	106	177	+ 67.0
Ethylidene aniline	40	80	+100.0
n-Ethyl-*p*-toluidine	354	1019	+187.9
Hexamethylenetetramine	92	70	− 23.9
-Naphthylamine	72	67	− 6.9
m-Nitroaniline	372	538	+ 44.6
o-Nitroaniline	109	74	− 32.1
p-Nitroaniline	127	134	+ 5.5
Xylidine	177	184	+ 4.0
Phenols			
o-Chlorophenol	118	130	+ 10.2
b-Naphthol	102	157	+ 53.9
p-Nitrophenol	68	55	− 19.1
o-Nitrophenol	39	50	+ 28.2
Thymol	79	62	− 21.5
Tribromophenol	443	497	+ 12.2
Nitriles			
Acetonitrile	312	397	+ 27.2
Phenylacetonitrile	136	134	− 1.5
Acids			
Benzoic acid	347	513	+ 47.8
Chloroacetic acid	254	206	− 18.9
Citric acid	288	351	+ 21.9
Formic acid	214	111	− 48.1
Malic acid	53	63	+ 18.9
Phenylacetic acid	97	113	+ 16.5
Propionic acid	115	68	− 40.9
Valeric acid	32	87	+171.9
Ethers			
Anethole	377	621	+ 64.7
Benzyl ether	523	1122	+114.5
Dichloroethyl ether	174	275	+ 58.0
Diphenylene oxide	73	88	+ 20.5
b-Naphthyl methyl ether	60	97	+ 61.7
p-Tolyl methyl ether	71	32	− 54.9
Sulfur compounds			
Amyl sulfide	136	269	+ 97.8

Compound	Number of Moths Caught: Standard bait	Number of Moths Caught: Test bait	Percentage Catch Compared with Standard
n-Butyl mercaptan	172	295	+ 71.5
n-Butyl sulfide	68	355	+422.1
n-Butyl disulfide	83	223	+168.7
Chloramine-T	86	110	+ 27.9
Ethyl mercaptan	296	396	+ 33.8
Methyl thiocyanate	168	204	+ 21.4
p-Toluenesulfonamide	49	72	+ 46.9
p-Toluenesulfonanilide	39	58	+ 48.7
p-Toluenesulfonic acid	147	89	− 39.5
p-Toluenesulfonyl chloride	55	41	− 25.5
Heterocyclic compounds			
Coumarin	101	110	+ 8.9
Furfuryl alcohol	141	121	− 14.2
Heliotropin	249	262	+ 5.2
Nicotine sulfate	251	426	+ 69.7
Pyridine	248	251	+ 1.2
Quinoline	43	35	− 18.6
Safrole	54	297	+450.0
Tetrahydrofurfural	55	39	− 29.1
Tetrahydrofurfural alcohol	88	86	− 2.3
Acetophenetidine	102	147	+ 44.1
dl-Alanine	87	65	− 25.3
Amyl salicylate	70	70	0.0
Anisaldehyde	195	159	− 18.5
Anthranilic acid	93	85	− 8.6
Aspartic acid	79	80	+ 1.3
Betaine hydrochloride	37	56	+ 51.4
Butyl anthranilate	90	79	− 12.2
Creosotinic acid	104	90	− 13.5
Cresylic acid	761	717	− 5.8
p-Cresyl acetate	392	288	− 26.5
Lactic acid	83	121	+ 45.8
p-Hydroxybenzaldehyde	53	78	+ 47.2
Indophenol	50	29	− 42.0
Isobutyl anthranilate	380	199	− 47.6
Methyl anthranilate	713	436	− 38.8
Salicylaldehyde	71	74	+ 4.2
Salol	306	309	+ 9.8
Triethanolamine	357	355	− 0.6
Vanillin	224	222	− 0.9
Hydrocarbons			
Amylene	327	342	+ 4.6
Cyclohexane	54	60	+ 11.1
Decahydronaphthalene	599	601	+ 0.3
Fluorene	57	98	+ 71.9
b-Methylnaphthalene	51	135	+164.7
p-Naphthalene	85	98	+ 15.3
Retene (neutral)	187	146	− 21.9
Xylene	292	362	+ 24.0
Terpenes and derivatives			
Borneol	484	943	+ 94.8
Bromocamphor	45	44	− 2.2
Camphene	243	323	+ 32.9
Camphor	75	64	− 14.7
Carvone	286	322	+ 12.6
Citral	99	383	+286.9
Dipentene	139	182	+ 30.9
Geraniol	195	320	+ 64.1
Geranyl acetate	269	701	+160.6
Geranyl butyrate	181	184	+ 1.7
Geranyl formate	439	597	+ 36.0
Hydroxycitronellal	132	165	+ 25.0
Limonene	111	232	+109.0
Linalyl acetate	125	233	+ 86.4
Linalyl caprylate	145	198	+ 36.6
Linalyl formate	120	175	+ 45.8
Menthol	93	94	+ 1.1
Phellandrene	49	44	− 10.2
Pinene	113	155	+ 37.2
Terebene	75	76	+ 1.3
Terpinene	112	137	+ 22.3
Terpineol	530	856	+ 61.5
Terpinolene	48	56	+ 16.7
Terpinyl acetate	355	708	+ 99.4
Halogen and nitro compounds			
Amylene dichloride	180	276	+ 53.3
Bromoform	760	849	+ 11.7
Bromostyrene	133	381	+186.5
Chlorobenzene	156	194	+ 24.4
p-Chloronitrobenzene	47	59	+ 25.5
p-Dibromobenzene	474	459	− 3.2
p-Dichlorobenzene	72	60	− 16.7
Hexachlorobenzene	47	49	+ 4.3
Methylene chloride	209	175	− 16.3
p-Nitrotoluene	30	47	+ 56.7
Pentachloroethane	596	903	+ 51.5
Propylene bromide	127	212	+ 66.9
Propylene chloride	62	107	+ 72.6
Products derived from natural sources			
Balsa of Peru	147	204	+ 38.8
Balsa of Tolu	164	144	− 12.2
Coal-tar oil	84	107	+ 27.4
Creosote (crude)	42	26	− 38.1
Creosote (white)	46	19	− 58.7
Hydrocarbon oil (neutral)	181	122	− 32.6
Pine-needle oil	299	79	− 73.6
Pine-tar oil	52	222	+326.9
Rosin spirits (crude)	75	160	+113.3
Spruce oil	447	606	+ 35.8
Turpentine	132	167	+ 26.5
Oils			
Amber	48	68	+ 41.7
Aniseed	307	618	+101.3
Apiol	85	88	+ 3.5
Bay	83	45	− 45.8
Bergamot	27	65	+140.7
Bitter almond	27	46	+ 70.4
Calamus	168	115	− 31.6
Capsicum	32	43	+ 34.4
Castor	106	112	+ 5.7
Cedar leaf	366	458	+ 25.1
Celery	84	91	+ 8.3

COMPOUND	NUMBER OF MOTHS CAUGHT		PERCENTAGE CATCH COMPARED WITH STANDARD
	Standard bait	Test bait	
Clove	66	84	+ 27.3
Copaiba	86	57	− 33.7
Coriander	284	340	+ 19.7
Cranberry	188	257	+ 36.7
Cypress	295	59	− 80.0
Elemi	87	41	− 52.9
Estragon	272	539	+ 98.2
Eucalpytus	565	523	− 7.4
Fennel	164	424	+158.5
Ginger	661	765	+ 15.7
Hemlock	293	439	+ 49.8
Horsemint	32	50	+ 56.3
Juniper berry	43	73	+ 69.8
Juniper wood	116	107	− 7.8
Kerosene (oxidized)	33	73	+121.2
Lavender	60	9	− 85.0
Lemon	166	327	+ 97.0
Lemon grass	391	406	+ 3.8
Lemon (Messina)	116	127	+ 9.5
Linseed	165	142	− 13.9
Mace	75	162	+116.0
Mustard seed	193	263	+ 36.3
Myrrh	191	155	− 18.8
Myrtle	151	25	− 83.4
Orange	511	767	+ 50.1
Origanum	72	27	− 62.5
Pennyroyal	173	201	+ 16.2
Peppermint	218	50	− 77.1
Petit-grain	307	139	− 54.7
Pimento	23	9	− 60.9
Poppy seed	411	382	− 7.1
Rapeseed	237	65	− 72.6
Rhodinol	546	866	+ 58.6
Rue	291	305	+ 4.8
Sage	162	17	− 89.5
Sassafras	163	379	+132.5
Sesame	546	376	− 31.1
Spearmint	168	43	− 74.4
Sweet basil	201	129	− 35.8
Sweet marjoram	94	13	− 86.2
Tansy	412	535	+ 29.9
Thuja	459	476	+ 3.7
Thyme	27	30	+ 11.1
Wintergreen	233	102	− 56.2
Wormseed	422	219	− 48.1
Ylang-ylang	69	38	− 44.9
Miscellaneous			
Ammonium fluoride	211	277	+ 31.3
Ammonium sulfate	133	210	+ 57.9
Birch-tar oil	434	500	+ 15.2
Lime-sulfur concentrate	69	79	+ 14.5

DISCUSSION.—Some idea of the probable significance of the differences that appeared in the results may be gained from a study of the variation to be expected entirely by chance. On the basis of a theoretical Poisson distribution, the approximate minimum differences required for significance (at odds of 19 to 1) would be as follows:

Number of moths caught	*Percentage difference (based on smaller record)*
25	78
50	50
100	33
150	26
200	22
300	17
400	15
500	13

These values represent the lowest threshold of possible significance. Materials failing to reach it need not be further considered; those reaching it do not positively show a real difference, but the possibility of one. Since the differences between the standard and test baits may have been caused in part by other factors, such as position in the tree, differences of less than 50 per cent have not been considered important. The materials showing increases of 50 per cent or more are grouped in the order of decreasing effectiveness as follows:

Materials showing increases of 300 per cent or more: Safrole, n-butyl sulfide, and pine-tar oil.

Materials showing increases of 100 to 300 per cent: Citral, n-ethyl-*p*-toluidine, bromostyrene, valeric acid, n-butyldisulfide, *b*-methylnaphthalene, geranyl acetate, fennel oil, bergamot oil, phenyl ethyl acetate, sassafras oil, kerosene (oxidized), mace oil, benzyl ether, rosin spirits (crude), limonene, aniseed oil, and ethylidene aniline.

Materials showing increases of 50 to 100 per cent: Terpinyl acetate, estragon oil, amyl sulfide, lemon oil, borneol, linalyl acetate, propylene chloride, fluorene, n-butyl mercaptan, bitter almond oil, juniper berry oil, nicotine sulfate, phenyl ethyl formate, diphenylquanidine, propylene bromide, anethole, isobutyl phenyl acetate, geraniol, *b*-naphthyl methyl ether, terpineol, acetaldehyde, rhodinol oil, dichloroethyl ether, ammonium sulfate, p-nitrotoluene, horsemint oil, beta-naphthol, amylene dichloride, pentachloroethane, betaine hydrochloride, and orange oil.

Materials showing decreases in attractiveness: Sage oil, sweet marjoram

oil, lavender oil, myrtle oil, cypress oil, peppermint oil, spearmint oil, pine-needle oil, rapeseed oil, origanum oil, pimento oil, heptyl alcohol, creosote (white), wintergreen oil, *p*-tolyl methyl ether, petit-gram oil, and elemi oil.

ADDITIONAL TESTS WITH PINE-TAR OIL.—In further tests of some of the most attractive materials, pine-tar oil gave consistently high catches of all broods of the codling moth. The material was added directly to the fermenting bait solution, instead of being placed in the evaporation cups. The increase in moths caught over those taken with the standard bait ranged from 94 per cent to 209 per cent, with an average of 158 per cent. The number of moths caught increased from 3192 to 8226.

Another experiment was conducted to determine the value of adding pine-tar oil to the standard bait. Two blocks of apple trees in an orchard were selected. In one block the standard bait was used, and in the other block the standard bait to which pine-tar oil had been added. The two baits were interchanged each day from April 13 to May 15. The bait containing pine-tar oil always captured more moths regardless of its location, and the total catch was 2347 moths as compared with 866 moths attracted to the standard bait.

Since other experiments have indicated that, when used alone, pine-tar oil is about half as attractive as the standard bait, the combination of pine-tar oil and standard bait is far superior to either of these materials alone. Further studies are necessary to determine the most efficient method of utilizing this oil and other materials of promise in a practical way for the control of the codling moth.

SUMMARY.—In an investigation having as its object the discovery of a suitable attractant to be used in baits as a supplementary control measure for the codling moth, a large number of chemicals were tested. This paper is the first of a series reporting the progress of the work, which involved the testing of about 250 compounds or mixtures.

The tests were made by floating a small vial of the material on the standard codling moth bait, composed of fermenting molasses solution, and comparing the number of moths captured with the number caught with molasses bait alone.

About 50 of the materials increased the attractiveness of the molasses bait from 50 to 450 per cent.

Certain other materials decreased the attractiveness of molasses bait either by masking its odor or by repelling the moths. Pine-tar oil, one of the most promising materials, was used in a number of additional tests, and gave a marked increase in catch over the standard molasses bait.—1-8-43.

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PAUL KNIGHT IN COSTA RICA

Mr. Paul Knight, a member of the staff of the Department of Entomology, University of Maryland since 1925 resigned effective January 31, 1943 to accept an appointment as entomologist on the research staff of the Cryptostegia Research Station of the Societe Haitiano-Americaine De Developpement Agricole, of Port-au-Prince, Haiti. For three months Mr. Knight was occupied in making a survey of the insect pests of *Cryptostegia grandiflora*, a possible emergency source of rubber which is being planted in Haiti under the sponsorship of the Export-Import Bank and the Rubber Development Corporation. Mr. Knight returned to the United States May 1st and accepted the position of Crop Entomologist to the Institute of Inter-American Affairs, Central American Section, and will serve this organization in the republics of El Salvador, Honduras, Nicaragua, Costa Rica and Panama. One of the chief functions of the Food Supply Division of this orgaization is to increase the production of vegetables and fruits in Central America in order that those countries will be able to export surpluses to strategic areas, particularly the Panama Canal Zone. Mr. Knight's address until further notice will be The American Ambassy, San Jose, Costa Rica.

Xanthone as an Ovicide and Larvicide for the Codling Moth

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Preliminary studies of the ovicidal and larvicidal values of xanthone in codling moth control, conducted at the Vincennes, Ind., laboratory in 1940 and 1941, demonstrated that the efficiency of the material as an ovicide was at least as great as its value as a larvicide and was considerably superior to that of the ovicidal sprays commonly used in that region.

At the present time mineral oil or combinations of mineral oil and nicotine sulfate are used by many growers as ovicidal sprays to supplement lead arsenate-bordeux mixture and nicotine bentonite programs directed against the larvae of the codling moth. These added materials are generally used in combination with two or three of the regular first-brood cover sprays, but nicotine sulfate with mineral oil is frequently applied later in the season, particularly as part of non-arsenical programs, and is considered more effective than oil alone.

Newcomer and Yothers (1932) showed that mineral oil has relatively little residual effect against eggs deposited after sprays were applied. Hough and Jefferson (1936) reported that the ovicidal efficiency of mineral oil was greatly reduced at oil dilutions of less than 1 per cent if bordeux mixture was included. These and other workers have shown by laboratory tests that it is necessary to use 0.75 to 1 per cent of oil to obtain efficiencies of 90 per cent or higher when the sprays are applied over the unhatched eggs. Oviposition in the 3-brood areas of the Middle West usually occurs daily from early in May to October, with the incubation period often becoming as short as 5 days in June, July, and August. Injury to fruit or foliage is likely to occur if mineral oil is used in excess of 1 per cent or in more than five or six applications. It is apparent, therefore, that if a large number of spray applications are to be avoided, an effective ovicide must be highly toxic to the insect as well as resistant to losses by decomposition, penetration, evaporation, and weathering. Very few published records are available to show the percentage of codling moth eggs that can be killed in actual field practice by materials thought to have ovicidal value. To supplement tests of the larvicidal efficiency of experimental treatments, it has been a standard practice at the Vincennes laboratory to test also the ovicidal efficiency of new materials.

Methods.—In order to duplicate orchard conditions as much as possible, 75 to 100 moths were confined in cages over twigs in the top and bottom sections of apple trees of average size in regular experimental plots. The cages were moved to new twigs at 1- or 2-day intervals and were temporarily removed during the application of the sprays, which were put on with a portable outfit from tower and ground at 550 pounds' pressure. The trees were sprayed to the point where run-off began from all parts, but no special effort was made to spray the twigs bearing eggs, since these were marked with inconspicuous tags and were seldom distinguishable to the spray men. Twigs bearing eggs were left undisturbed until the most advanced eggs began to hatch, usually 5 or 7 days after deposition. The twigs were then removed from the tree and the cut ends placed in water to prevent wilting. They were held outdoors, but were sheltered from rain, direct sunlight, and high winds. The removal and subsequent protection of the twigs was necessary to avoid the scaling off and loss of empty eggshells. Since the ovicides frequently retarded development, the examination for mortality was deferred until 10 to 12 days after the first eggs had hatched.

Experiments in 1940.—In 1940, moths were confined on Grimes Golden twigs for 2 days before and 2 days after the application of the second and third cover sprays on May 31 and June 11, respectively. Approximately 25 gallons of spray material were used per tree for each application.

The results from three treatments with different combinations of materials are given in table 1. Larvicidal efficiencies as determined by the laboratory-field method (Steiner 1939) are included for comparison.

Under the conditions of this experiment xanthone with zinc sulfate and sodium

Table 1.—The ovicidal and larvicidal efficiencies of xanthone in comparison with those of other commonly used sprays. Vincennes, Ind., 1940.

Plot	Materials, Quantities per 100 Gallons	Eggs Deposited		Eggs Dead, Per Cent	Larvicidal Efficiency, Per Cent
		Time	Number		
1	4 lbs. lead arsenate, 0.75 lb. copper sulfate, 1.5 lbs. lime, 2 qts. mineral oil[1]	Before spray	139	31	31
		After spray	176	11	54
2	1 pt. nicotine sulfate (40%) 5 lbs. bentonite, 1 lb. sodium oleate, 2 qts. mineral oil	Before spray	124	10	53
		After spray	269	10	69
3	2 lbs. xanthone, 4.5 oz. zinc sulfate, 1.7 lbs. sodium oleate	Before spray	370	73	12
		After spray	116	72	31

[1] A proprietary summer oil of the emulsive type containing 97 per cent of oil, having 91 per cent of unsulfonatable residue and a viscosity at 100° F. of 58 seconds. The same oil was used in the other experiments reported herein.

oleate was considerably more effective as an ovicide than a half-per cent mineral oil with either the lead arsenate-bordeaux or nicotine bentonite-soap combination. It was also evident that eggs laid on the spray deposits were affected by the xanthone as much as those which had been deposited before the spray was applied, and that xanthone was more efficient as an ovicide than as a larvicide.

Because of these results a more extensive experiment was arranged beginning July 22. Moths were caged on trees in two plots, one sprayed with xanthone and the other with nicotine sulfate and mineral oil.[1] At 2-day intervals until August 11 the cages were moved to new locations and new moths introduced. Two spray applications, the sixth and seventh cover sprays, were made during the experiment.

The eggs were exposed to 0.22 inch of rain on July 23, a trace on Juy 31, and 0.45 inch on August 12. The temperature averaged approximately 6 degrees above normal during the experiment. The daily maximum averaged 96° F. and ranged from 83° on August 10 to 104° on July 29, falling below 91° only on the former date. The minimum temperature averaged 71° and ranged from 58° on August 7 to 77° on July 23 and 25.

The comparative ovicidal effects of the two treatments against eggs deposited within the 2-day periods are shown in table 2.

[1] Three quarts of mineral oil were used per 100 gallons in the sixth cover spray and 2 quarts in the seventh, with 0.67 pint of nicotine sulfate in each.

Because of the high temperatures that prevailed it is probable that penetration of the mineral oil into the foliage and volatilization of both oil and nicotine reduced the effectiveness of this treatment more rapidly in the interval between sprays than would occur under lower temperatures.

It has been the writers' observation, however, that ovicides rarely give as good results under field conditions as in the laboratory. A more rapid absorption of oil into the tissues of growing plants than occurs in foliage or fruit sprayed after its removal from the tree may be one of the important factors concerned.

Table 2.—Relative values of xanthone and oil-nicotine sulfate sprays as midsummer codling moth ovicides. Vincennes, Ind., 1940.

Dates of Egg Deposition	Xanthone		Oil-Nicotine Sulfate	
	Number of Eggs	Per Cent Eggs Dead	Number of Eggs	Per Cent Eggs Dead
July 22–24	2,279	24.8	378	32.0
July 24, 6th cover spray applied				
July 24–26	1,946	49.7	1,642	22.0
July 26–28	1,779	39.1	1,231	23.3
July 28–30	1,847	34.9	667	18.1
July 30–Aug. 1	2,770	26.5	2,466	14.5
Aug. 1–3	2,017	23.3	1,573	48.3
Aug. 3–5	2,104	27.7	1,654	44.2
Aug. 5–7	1,429	21.2	1,601	25.0
Aug. 7, 7th cover spray applied				
Aug. 7–9	1,371	30.4	911	18.8
Aug. 9–11	2,850	52.8	1,751	13.3
Total				
In tops of trees				
Eggs on leaves	8,822	38.2	5,291	21.1
Eggs on fruit	3,277	22.0	2,331	33.0
In lower parts of trees				
Eggs on leaves	6,231	34.7	3,906	20.0
Eggs on fruit	2,062	30.4	2,346	37.3
All eggs	20,392	33.7	13,874	25.5

Since the eggs began hatching on the fifth day after deposition, those deposited from July 22 to 24 were subjected for at least 3 days to deposits from the sixth cover spray. Eggs laid between July 24 and August 1 were practically all subjected to the toxicant over which they were deposited and also to spray residues redeposited on them as a result of weathering from higher in the tree.

Xanthone appeared to be most effective against eggs deposited soon after the spraying. The low resistance of this material to weathering accounts for this, since such eggs tie down the deposit and are thus subjected more to it. The mineral oil-nicotine sulfate combination was most effective against eggs which had reached the black-spot stage when the spray was applied. Most of the eggs deposited from August 1 to 5 which had not hatched when the seventh cover spray was applied on August 7 were in this condition.

Xanthone deposits on foliage were more effective than those on fruit, probably because of heavier residues which appeared to have accumulated on the former. The oil-nicotine treatment was more effective against eggs on fruit than against those on foliage, presumably because of greater penetration of the oil into the leaf tissue with resulting loss of toxicity. This difference in effectiveness of the ovicides on foliage is important because as many as 94 per cent of the codling moth eggs may be deposited on the leaves during the course of a season.[1]

Xanthone deposits on fruit in the lower parts of the trees were found to be more effective than those in the top. Deposits of this material weathering from apples and foliage higher in the tree appear to build up more deposit in the stem basin of low-hanging fruit than on foliage or on other fruit surfaces. Deposits of mineral oil and nicotine sulfate would be less likely to weather off and be redeposited in lower parts of the tree.

Of the eggs deposited on leaves in the xanthone plots, 43.4 per cent of those on the upper surface were killed as compared with 31.5 per cent of those on the lower surface. There was no significant difference between the effectiveness of the oil-nicotine sprays on upper and lower surfaces of the leaves.

[1] Unpublished data from the Vincennes, Ind., laboratory.

The larvicidal efficiencies of the spray deposits on fruit before and after application of the two sprays were as follows:

	Xanthone, Per Cent	Oil-Nicotine, Per Cent
Before 6th cover, July 22	5.3	74.4
After 6th cover, July 25	47.2	86.7
Before 7th cover, August 6	22.9	71.2
After 7th cover, August 8	38.7	86.4
Two weeks after 7th cover, August 21	26.1	76.0

These data support visual observations which indicated that the xanthone deposits were not sufficiently adhesive to last long between sprays.

The mineral oil-nicotine sulfate treatment may have had some effect in decreasing the amount of oviposition, since approximately the same numbers of moths were placed in the two sets of cages each time they were transferred. This method of comparing the effects of the sprays on the adult moths, however, is not considered reliable.

EXPERIMENTS IN 1941.—In 1941 a deposit-building adhesive recommended by the manufacturer was used with the xanthone. The mean particle size of the 1941 material was 3.75 microns, as determined by J. E. Fahey, Division of Insecticide Investigations, Bureau of Entomology and Plant Quarantine. A single experiment was so arranged that the effects of the fourth cover spray could be observed. Eggs were deposited from 2 to 48 hours before the spray applications, and from 2 to 48 hours afterwards, on 17-year-old Golden Delicious trees requiring an average of 30 gallons of spray material per tree for thorough coverage. The results are given in table 3.

In plot 2 the eggs deposited prior to the fourth cover spray were subjected only to covering deposits of xanthone, since that material was included only in that application. Although the ovicidal efficiency was less than that obtained early in 1940, rainfall after the application was heavy. A rain of 0.30 inch on June 9 soon after the spray was applied immediately reduced the larvicidal efficiency from 77.4 to 68.2 per cent. Additional rains totalling 1.75 inches fell between June 9 and 13.

The results with the lead arsenate (plot 1) were very similar to those obtained with the same formula in 1940 (Table 1).

Data obtained at harvest in 1941 from single-tree plots indicated that as sole protection against larvae of the second and third broods xanthone was less effective than lead arsenate, allowing 13 worm entrances per 100 apples as compared with 3.2 for the latter material. The low resistance of xanthone to weathering and its low larvicidal efficiency as compared with lead arsenate made fruit sprayed with xanthone very susceptible to third-brood attack resulting from interplot moth migration.

DISCUSSION.—The higher ovicidal efficiencies obtained with xanthone early in the season over those obtained in midsummer are believed to have resulted from the longer incubation period and the closer spacing of sprays early in the season.

The way in which xanthone kills the eggs is not known. Its effect on the developing embryo is often delayed so that death occurs in the black-spot stage.

There was some lengthening of the incubation period of eggs that survive the xanthone sprays. Before the black-spot stage was reached, most of the eggs became orange colored, as did many of the larvae that succeeded in hatching. Juices pressed from partly developed eggs were pink, indicating pentration either by the xanthone or by the pink dye used to color the material.

Ovicidal sprays such as oil or oil-nicotine appear to be of less value where three broods of the codling moth occur than in the two-brood areas because of the longer period of attack, the shorter incubation period, the higher temperatures which may accelerate loss of oil deposits, and the injury that results if oil deposits are maintained over too long a period.

SUMMARY.—Preliminary studies of xanthone, applied in regular cover sprays to apple trees on which codling moth eggs had been or were subsequently deposited by caged moths, indicated that early in the season this material was considerably more effective as an ovicide than 0.5 per cent mineral oil with lead arsenate and a weak bordeaux mixture (Table 1).

In midsummer xanthone killed 33.7 per cent of 20,392 eggs deposited between July 22 and August 11, during which time 2 spray applications were made. Nicotine sulfate (1–1200) with mineral oil (0.75 and 0.5 per cent) killed only 25.5 per cent of 13,874 eggs during the same period (Table 2).

Xanthone was most effective against eggs deposited soon after the spray application, whereas oil-nicotine was most effective against eggs that were in the black-spot or advanced red-ring stages at the time the sprays were applied. Xanthone was more effective on foliage, where most of the eggs are deposited, than on fruit, where its deposits appeared lighter. Oil-nicotine was more effective on fruit than on foliage, presumably because penetration and loss of the oil from other causes was more rapid from the leaf than from fruit surfaces.

Xanthone was generally less effective as a larvicide in laboratory-field tests whereas the reverse was true of oil-nicotine and the lead arsenate-bordeaux-oil com-

Table 3.—A comparison of the ovicidal and larvicidal effects of xanthone and lead arsenate-bordeaux-oil sprays applied June 9, 1941.

Plot	Materials, Quantities per 100 Gallons	Eggs Deposited		Eggs Dead, Per Cent	Larvicidal Efficiency, Per Cent
		Time	Number		
1	4 lbs. lead arsenate, 0.75 lb. copper sulfate, 1.5 lbs. lime, 2 qts. mineral oil	Before spray	2,176	29.9	30.0
		After spray	1,685	14.7	42.1
2	2 lbs. xanthone, 1 qt. kerosene, 3 oz. soap, 2 oz. zinc sulfate[1]	Before spray	1,645	56.9	30.0
		After spray	1,226	65.7	68.2
3	Not sprayed after petal fall	Before spray	1,296	4.6	0
		After spray	169	5.3	0

[1] Used only in 4th cover spray. Prior treatment same as for Plot 1. Soap and zinc sulfate supplied by manufacturer and may have contained supplementary materials.

binations. In a field test the lead arsenate treatment gave better control of third-brood larvae than xanthone, partly because of the low resistance of the latter to weathering during the long period between the final cover spray and harvest and partly because of interplot migration of moths.

In three-brood areas, where the incubation period is as short as 5 days and eggs may be deposited daily from early May to October and where high temperatures shorten the effective period of oil sprays, their ovicidal value is likely to be less than under the lower temperatures of two-brood areas.—1-29-43.

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Effectiveness of Cube and Derris Resins in a Tank Mix and an Emulsive Oil against California Red Scale

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The addition of powdered derris or a pine oil extract of derris has been shown by English (1939) to increase the effectiveness of certain oil sprays against the purple scale. He found that the addition of derris to oil emulsions prepared with diglycol stearate, diglycol oleate, and sodium oleyl sulfate was more effective than combinations with tank-mix oils. In recent work on the California red scale, combinations of cube or derris resins and oil with a suitable mutual solvent, or "solubilizer," have received more attention that the powdered root. The solutions or mixed solutions and suspensions of the resins in oil obtained in this way have been shown to be more effective than oil alone when used with tank-mix and emulsive oils (Ebeling 1940, 1941), glue emulsions (Cressman 1941b), or various other emulsions (McBeth & Allison, 1941). In the following report, some data on the comparative effectiveness of combinations of cube and derris resins in a tank-mix oil and in an emulsive oil are presented.

Mortality counts were limited to female scales in the gray adult and mature stages on the older wood. Approximately 100 scales on each of 20 to 25 branches were examined in each plot. Natural mortality was estimated just before the spray application. The method of measuring oil deposits was described by Dawsey & Hiley (1937) and modified by Cressman (1941a).

The light, light medium, and medium oils met the specifications of the California Department of Agriculture, as published by Cox (1938). The unsulfonatable residues of the extra light oil and kerosene were 86 and 97 per cent, respectively. The temperatures at which distillation began, and at which 50 per cent and 90 per cent distilled were, respectively, 360°, 415°, and 457° F. for the kerosene, and 514°, 570°, and 643° F. where the extra light oil was used.

Numerous field sprays with cube resins in a commercial brand of emulsive oil said to contain 1 per cent of glyceryl oleate were applied in 1939 and 1940. A mixture of 2 parts by volume of dibutyl phthalate and 1 part of trichloroethylene was used as an intermediate solvent. This combination produces a mixed solution and suspension of resins in oil. Whenever several concentrations of resins were applied, the scale mortality increased with increasing concentrations of resins. One series of tests with 1.5 per cent of light medium oil and cube resins containing 28 per cent of rotenone gave the following results:

Cube resins in oil	*Scales killed*
Per cent by weight	Per Cent
0	45
0.51	60
0.76	84
1.52	98

In another series of tests, sprays containing 1, 1.5, and 2 per cent of a medium oil were applied with cube resin concentrations of 0, 0.47, 0.76, 1.52, and 2.27 per cent in oil at each oil dosage. The increment of kill increased at a rate proportional to the logarithm of the cube resin concentration. Similar results have been obtained in laboratory tests with glue emulsions (Cressman 1941b).

Table 1.—Results of sprays of volatile petroleum fractions with and without derris resins applied to the California red scale on lemon trees.

Oil	Concentration of Resins, Per Cent	Scales Killed, Per Cent
2 per cent light	0	64.0
	0.5	90.1
	1.0	93.2
3 per cent extra light	0	92.8
	0.33	99.3
	0.67	99.0
5 per cent kerosene	0	34.7
	0.20	74.1
	0.40	73.1

In 1941, experiments with more volatile petroleum fractions were initiated, using tank-mix oils, with 4 ounces of blood albumen spreader per 100 gallons. Tests with 5 per cent of kerosene containing 5 per cent, by volume, of the dibutyl phthalate-trichloroethylene mixture produced considerable defoliation; and therefore *Cardolite* (Ebeling 1940) was substituted as a mutal solvent in the proportions of 1 part, by weight, of resins to 5 parts of *Cardolite*. This combination produces an apparent solution of resins in oil. Sprays with a light spray oil, kerosene, and an intermediate fraction designated as "extra light," with *Cardolite* and derris resins, were applied in May 1941. The derris resins used in these and subsequent tests contained 33 per cent of rotenone. The results are summarized in table 1.

Each 100 gallons of spray contained 38 grams of resins at the lower concentration and 76 grams at the higher. It is evident, without any statistical analysis, that the addition of derris resins increased the mortality, but that doubling the concentrations produced no further increase in kill. The oil deposits were not known, since satisfactory methods of measuring deposits of the lighter petroleum fractions had not been developed when these sprays were applied.

Experiments were next made with a medium tank-mix oil using both *Cardolite* and the dibutyl phthalate-trichloroethylene mixture as solvents. Two concentrations of derris resin were used and each combination was applied in duplicate. The results are summarized in table 2.

Analysis of the variance showed no significant differences between derris resin concentrations or solvents with respect to oil deposits or scale mortality. Other tests have shown that both solvents were about equal to a like amount of oil in their toxicity to the scales.

The consistent failure to obtain better kill with higher derris resin concentrations in a tank-mix oil was in strong contrast to the earlier results with an emulsive oil. These tests with the two types of spray mixtures had been made at different times, in different orchards, and included different lots of cube or derris resins. Parallel applications in a block of trees were made in October 1941, using 1.75 per cent of the same brand of light medium emulsive oil used in the earlier sprays along with a tank-mix oil. These were followed by

Table 2.—Results of sprays with 1.75 per cent of tank-mix medium oil and derris resins, with 4 ounces of blood albumen spreader per 100 gallons, on the California red scale.

Derris Resin Concentration, Per Cent	*Cardolite*		Dibutyl Phthalate-trichloro-ethylene		Average	
	Oil deposit, µml. per sq. cm.	Scales killed, per cent	Oil deposit, µml. per sq. cm.	Scales killed, per cent	Oil deposit, µml. per sq. cm.	Scales killed, per cent
0.57	87	66.4	93	72.3	90	69.3
1.14	86	67.8	83	71.4	84.5	69.6
Average	86.5	67.1	88	71.8		

spray tests in November in which a light medium oil was divided into two lots. One part was mixed with 1 per cent, by volume, of glyceryl monooleate to make an emulsive oil, which was applied at a concentration of 1.75 per cent. The other part was applied as a tank-mix oil, at 1.5 per cent without blood albumen spreader.

The dibutyl phthalate-trichloroethylene mixture was used as a solvent in the proportion of 6.7 ml. of solvent mixture to 1 gram of derris resins. The results are summarized in table 3.

In the October tests, 1.14 per cent of derris resins was significantly better than 0.57 per cent of resins used in emulsive oil, but there was no difference between these two concentrations in a tank-mix oil. The results of parallel experiments, therefore, were consistent with the more extensive tests in which these types of oils had been applied separately. The observed mortalities with 0.57 per cent of resins were higher than those obtained with 0.28 per cent in both oils, but the differences were short of statistical significance. There is little doubt that the addition of derris resins to a tank-mix oil in concentrations of 0.57 per cent or more increased the effectiveness of the sprays, but measurement of the effect of lower concentrations of resins would require more extensive tests. There were no significant differences in the oil deposits in the October sprays, but in every case the emulsive oil was more effective than the comparable tank-mix oil.

Since no spreader was added in the November sprays, the only point of difference in the two oils was the presence of glyceryl monooleate in the emulsive oil. In these tests the tank-mix oil again failed to show any significant difference between 0.57 and 1.14 per cent of derris resins. Evidently this failure to improve the mortality when concentrations were increased above some undetermined optimum was not dependent on the blood albumen spreader. The difference in behavior of the two types of oil may be related to a change in the physical properties of the oil which are affected by the oil-soluble emulsifier. A number of changes of this kind have been described by Knight & Cleveland (1934). If so, the dosage-mortality relations may be affected by the emulsifier or by the mutual solvent incorporated with the oil. Only one type of emulsifier and one solvent in emulsive oil have been examined in these experiments.

Table 3.—Results of sprays with an emulsive and tank-mix oil against the California red scale.

Concentration of Derris Resins, Per Cent	Tank-mix Oil: Oil deposit, μml. per sq. cm.	Tank-mix Oil: Scales killed, per cent	Emulsive Oil: Oil deposit, μml. per sq. cm.	Emulsive Oil: Scales killed, per cent
October Sprays				
0	162	54.2±4.0	154	71.6±4.5
0.28	159	68.4±6.4	156	85.8±3.5
0.57	159	82.6±4.5	164	92.3±1.4
1.14	166	80.2±4.4	160	97.6±0.7
November Sprays				
0.57	135	65.9±4.5	114	55.7±5.4
1.14	145	56.3±4.4	116	76.3±3.9

SUMMARY.—Experiments with a tank-mix oil showed that addition of derris resins increased the mortality of the California red scale but that 1.14 per cent of resins in oil was no more effective than 0.57 per cent. In one type of emulsive oil, scale mortality was proportionate to the amount of cube or derris resins in the oil over a wider range of resin concentrations.—12-10-42.

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Calcium Cyanide Fumigation for the Western Thrips

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The western thrips, *Frankliniella occidentalis* (Pergande) is one of the most injurious pests affecting ornamental plants in California. Roses, carnations, fuschias, hibiscus, and snapdragons are particularly susceptible to damage, which is characterized by stunting of new growth and flower-scarring. *F. occidentalis* is also responsible for injury at times to nectarine, plum, peach, apricot, grape, orange, cotton, bean, cucumber, cantaloupe, squash, onion, carrot, beet, and alfalfa. The host range includes practically all types of plants, but breeding is confined mostly to succulent plants or to plants in flower.

On greenhouse-grown carnations and roses flower thrips represent the chief insect problem in California. Three species of thrips are primarily involved, *Frankliniella occidentalis* (Perg.), *F. minuta* Moulton, and *Thrips tabaci* Lind. Of these, the first[2] greatly predominates.

The methods of control most commonly used for flower thrips affecting greenhouse-grown cut flowers are nicotine sulfate spray, nicotine fumigation, tartar emetic spray, and napthalene fumigation.

Some growers have used calcium cyanide[3] fumigation on carnations. The inconsistent degree of control and of plant injury has discouraged wider use of this material. Apparently the diversity of results can be laid to variations in fumigation procedure, to imperfect knowledge of the effects of different dosages and lengths of exposure on thrips, and to varietal differences in sensitivity of carnations to cyanide fumes.

VARIETAL SUSCEPTIBILITY TO INJURY.—In preliminary tests in a reasonably tight greenhouse range, apparently good flower thrips control on mixed varieties of carnations was obtained by the use of 0.5 ounce of *Cyanogas* to 1000 cubic feet in overnight fumigation. No precautions were taken with respect to withholding irrigation prior to treatment and, probably as a result of this circumstance, some injury in the form of whitened areas on leaves and sepals became evident 4 days after fumigation. Recently transplanted rooted cuttings were most noticeably affected. None of these were killed, however, and the injury was hardly visible after several weeks of the normal practice of "pinching back." The degree of injury to mature plants differed greatly according to varieties. Dairy Maid and Pharaoh were most affected and the majority of flowers present on these varieties were rendered unsaleable by the discoloration of the calyx. Orchid Beauty, Puritan, and Maine Sunshine were somewhat less damaged. A slight burn which did not influence the sale of the flowers was noted on Spectrum Supreme, Pelargonium, Rigoletta, and Olivette. No injury was observed on Dimity, Joanne Marie, Golden Wonder, and Orange Wonder.

EFFECTS OF CALCIUM CYANIDE FUMIGATION ON *Frankliniella Occidentalis*.—In order to obtain information on the reaction of *F. occidentalis* to calcium cyanide fumigation, a series of greenhouse fumigation experiments were conducted by the writer during the summer and fall of 1942 in Los Angeles. Blossoms of common mustard (*Brassica* spp.), which were known to harbor numerous thrips, were picked just prior to fumigation and placed in open-mouth glass containers of various sizes. These containers were placed at random in the greenhouse. Tests were made in two empty greenhouses, one containing 20,400 cubic feet, and the other containing 1600 cubic feet. The thrips were subjected to 3-hour and overnight exposures as well as to *Cyanogas G-Fumigant* dosages of 0.375, 0.5, 0.75, and 1.0 ounce per 1000 cubic feet. At the end of the fumigation period the containers were removed and kept in a cool dark place until the thrips could be examined. By observation it was determined that under these circumstances the error resulting from the escape of thrips from the mustard blossoms in the glass containers during and after fumigation was negligible. Counts were made 2 hours or more after treatment to permit recovery of the thrips from the stupefying effect of the cyanide fumes. The flowers were shaken onto black paper and the thrips

[1] The writer is indebted to H. K. Collins and W. Kirstein for assistance in carrying out certain of the greenhouse experiments.

[2] In this paper *F. occidentalis* and *F. moultoni* Hood are considered to be identical.

[3] *Cyanogas G-Fumigant*, stated to contain not less than 42 per cent calcium cyanide.

Table 1.—Effect of calcium cyanide fumigation on *Frankliniella occidentalis* (Perg.)

CYANOGAS DOSAGE IN OZ. PER 1000 CU. FT.	LENGTH OF EXPOSURE IN HOURS	GREENHOUSE[1]	AVERAGE TEMPERATURE DEGREES F.	AVERAGE RELATIVE HUMIDITY	TOTAL NUMBER OF THRIPS		PER CENT MORTALITY	
					Larvae	Adults	Larvae	Adults
Check (not treated)	—	2	70.0	72.0	83	252	2.4	1.2
0.375	3	1	67.0	90.0	73	89	6.8	6.7
0.375	3	2	70.0	88.0	29	42	3.4	0.0
0.5	3	1	66.0	90.0	45	345	6.7	48.7
0.5	3	1	70.0	92.5	37	126	2.7	58.7
0.5	3	2	71.0	80.0	69	184	20.3	52.2
0.5	3	2	64.0	90.0	77	197	33.8	55.8
0.75	3	1	67.0	85.0	20	844	25.0	59.4
0.75	3	1	69.0	95.0	127	248	35.4	76.6
0.75	3	2	82.0	60.0	41	172	21.9	78.4
1.0	3	1	69.0	84.0	39	291	38.5	80.1
1.0	3	1	66.5	87.5	63	219	58.7	73.5
1.0	3	2	77.0	70.0	92	346	36.0	81.5
0.375	13	1	66.0	87.0	96	143	6.3	6.3
0.375	14	2	66.0	90.5	137	79	29.2	30.4
0.5	14	1	65.0	88.5	104	619	47.1	91.1
0.5	13	1	68.0	91.0	67	468	46.3	85.9
0.5	14	2	68.5	84.0	108	243	83.3	98.5
0.5	13	2	63.5	92.5	104	237	84.6	95.8
0.75	14	1	66.5	88.0	79	1094	82.3	99.2
0.75	13	1	68.5	91.5	692	639	91.4	98.7
0.75	14	2	81.0	55.5	157	156	67.5	94.4
1.0	14	1	67.5	89.0	121	1184	95.0	99.7
1.0	13	1	66.0	88.5	70	409	100.0	99.0
1.0	14	2	74.5	67.5	79	488	88.6	99.2

[1] Greenhouse 1 contained 20,400 cubic feet and greenhouse 2 contained 1600 cubic feet.

were counted individually. In the tests recorded in table 1 counts were made of more than 9000 adults and 2600 larvae.

It is apparent from an examination of table 1 that there was a considerable range of mortality at any given dosage and length of fumigation. Factors contributing to this condition were the difference in volume and leakage potential of the two greenhouses used, and the varying temperature and humidity. In spite of variation in results the following generalizations can be made: (1) The larvae were decidedly more resistant than the adults. (2) Overnight fumigation was much more effective than a 3 hour exposure. (3) Little or no mortality was obtained with a *Cyanogas* dosage of 0.375 ounce.[1]

CONCLUSIONS.—Reasoning from average figures it is possible to formulate an expected mortality range which would be applicable to a reasonably gas-tight greenhouse comparable to those used by the writer. With a 3 hour exposure larval mortality should be slight at *Cyanogas G-Fumigant* dosages of 0.375 ounce and 0.5 ounce, about 27 per cent at 0.75 ounce, and 44 per cent at 1.0 ounce. For the same exposure adult mortality should be slight at 0.375 ounce, about 54 per cent at 0.5 ounce, 71 per cent at 0.75 ounce, and 78 per cent at 1.0 ounce. For overnight fumigation larval mortality should be slight at 0.375 ounce, about 63 per cent at 0.5 ounce, 80 per cent at 0.75 ounce, and 94 per cent at 1.0 ounce. Adult mortality for the same exposure should be slight at 0.375 ounce, about 90 per cent at 0.5 ounce, 97 per cent at 0.75 ounce, and 99 per cent at 1.0 ounce.

[1] When not specified, *Cyanogas* dosages refer to the quantity used per 1000 cubic feet.

From the standpoint of practical control it would probably be necessary to fumigate weekly or bi-weekly during the months of heaviest thrips infestation. *Cyanogas* dosages of 0.75 ounce per 1000 cubic feet for 3 hours or 0.5 ounce for an overnight exposure could be used. If the greenhouse were leaky, the dosages would have to be correspondingly increased. In all probability the 3 hour exposure at 0.75 ounce, while less efficient in thrips control, would be much safer to use on carnations than the overnight exposure at 0.5 ounce. One commercial carnation grower in southern California has used *Cyanogas* for several years at a dosage of 1.0 ounce per 1000 cubic feet for a 3 hour exposure without objectionable injury. However, before this material could be used on a large scale, more information is needed on differences in varietal response of carnations to fumigation, as well as the effect of humidity, temperature, post-shading, and other factors on likelihood of injury. Many of the varieties which are severely scarred by thrips, such as Spectrum Supreme, Pelargonium, and Rigoletta, are resistant to injury from cyanide fumes. It appears that regardless of the means of control used, it would be profitable for a grower to segregate such varieties in a single greenhouse. It would then be safer and more economical to use fumigation than it would be if miscellaneous varieties were mixed in a single house. In the light of present knowledge the following precautions should be taken when carnations are fumigated: (1) Irrigation should be withheld for 24 hours before fumigation; (2) there should be no standing water in the greenhouse; (3) nights on which the temperature falls sharply should be avoided; (4) walks should be sprinkled before fumigation only if the air is very dry; (5) the greenhouse should be sealed as tightly as possible; (6) rooted cuttings and recent transplants should not be exposed to fumigation.

SUMMARY.—Greenhouse tests were made to determine the effect of calcium cyanide fumigation on the western thrips, *Frankliniella occidentalis* (Perg.). In experiments involving greenhouse carnations it was found that varieties differed greatly in their reaction to cyanide fumes. Poorly established plants and the varieties Pharaoh and Dairy Maid were particularly susceptible to injury. Orchid Beauty, Puritan, and Maine Sunshine were more resistant but less so than Spectrum Supreme, Pelargonium, Rigoletta, Olivette, Dimity, Joanne Marie, Golden Wonder, and Orange Wonder. Tests conducted in empty greenhouses with thrips in mustard blossoms revealed the following points: (1) Thrips larvae were much more resistant to fumigation than the adults. (2) Thrips mortality was poor at less than 0.5 ounce of *Cyanogas G-Fumigant* per 1000 cubic feet. (3) Overnight fumigation gave much higher kills than exposure for 3 hours. (4) High adult mortality was obtained at a dosage as low as 0.75 ounce for a 3 hour fumigation and 0.5 ounce for an overnight exposure. It was concluded that during periods of heavy infestation, weekly or bi-weekly fumigation for 3 hours at a dosage of 0.75 ounce of *Cyanogas G-Fumigant* per 1000 cubic feet should give adequate control of *F. occidentalis* in a reasonably tight greenhouse. This should not result in objectionable plant injury if proper precautions are observed. However, before calcium cyanide fumigation can be used on carnations on a large scale, more information is needed with respect to varietal response to cyanide fumes, and the effects of humidity, temperature, and post-shading.—12-7-42.

McDONALD TO AID MEXICO IN CONTROLLING PINK BOLLWORM

To aid Mexico in combating the pink bollworm, R. E. McDonald, who since 1929 has been in charge of the Department of Agriculture's field work for control of this pest, has been transferred to Mexico with headquarters at Torreon, the Department said today. McDonald has made many contributions to the methods of combating the pink bollworm and detecting its presence. He is thoroughly familiar with the control work conducted in Mexico as well as in the United States.

Substitutes for Tartar Emetic and Brown Sugar in the Control of the Gladiolus Thrips

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At the end of 1941 tartar emetic and brown sugar in sprays had become almost universally adopted as a field control for the gladiolus thrips, *Taeniothrips simplex* Morison, which was largely based on the work of Richardson (1934), Nelson (1938), and Johnson and Smith (1940). War conditions, which cut off the usual source of antimony from the Orient and initiated the rationing of sugar to conserve supplies, made it necessary to search for substitutes for these materials. Since the susceptibility of the gladiolus thrips to tartar emetic resembles that of several other important economic species, including the citrus thrips, *Scirtothrips citri* (Moult.) (Boyce and Persing, 1939), the onion thrips, *Thrips tabaci* Lind. (Anderson and Walker, 1940, and Eichmann, 1940, 1942), and the cotton thrips, *Frankliniella occidentalis* (Perg.) (Eyer & Medler, 1941), any substitutes might prove valuable in combating these latter forms on other crops.

When the experiments for 1942 were being planned, tartar emetic, as well as sugar, was prohibited for use on such crops as gladiolus. Because previous workers had thoroughly investigated the field of possible insecticides for this insect, the chances seemed remote for finding effective materials among new untried compounds. It was, therefore, considered necessary to find substitute insecticides among the few available and relatively effective ones, of the many tested by previous workers, when combined with one or more of the available sirups or molasses products. Among these were nicotine sulfate, lead arsenate, and paris green.

Richardson (1934) showed in laboratory tests that 40 per cent nicotine sulfate (1–600) was nearly equally effective when combined with blackstrap molasses, sorgo sirup, and corn sirup, but slightly less so with honey; also, that toxicity increased to 98 per cent if a 1–400 dilution of nicotine was used with molasses. Subsequent to Richardson's work, R. H. Nelson, according to an unpublished report for 1934, tested nicotine sulfate (40 per cent) at the rate of 1–600, with blackstrap molasses (5 gal. per 100), but the control was 47 per cent as compared with 85.45 per cent obtained with the paris green-brown sugar spray. Nelson also observed extensive black desposits on the foliage. Nelson (1938) reported that lead arsenate (6 lbs.) in combination with brown sugar caused less injury than paris green or other arsenicals in field tests, and was nearly as efficient in control. H. H. Richardson (in unpublished experiments) found that 0.4 lb. of paris green combined with 3 gallons of molasses in 100 gallons of spray was equal to the 2-pound rate when combined with 64 pounds of brown sugar.

The 1942 experiments were, therefore, planned to include these materials in combination with available sirups and molasses as found or produced locally in various parts of the country.

GREENHOUSE EXPERIMENTS.—In the spring of 1942, four applications of 15 treatments each, including a check, were made in the greenhouse to 30 plots of the gladiolus variety La Paloma, each plot containing 50 plants. Tartar emetic, 40 per cent nicotine sulfate, sodium antimony lactophenolate, and two thiocyanates were used in combination with brown sugar or table sirups and molasses. Results were taken by recording the number of living thrips in all stages found on foliage or in leaf sheaths on 10 plants selected at random from each plot 1 week after the last spray. The results are recorded in table 1. In this test tartar emetic was practically equally efficient whether combined with brown sugar (No. 2), corn sirup sweetened with cane sirup or granulated sugar (Nos. 3, 5), or with a dark cane molasses (No. 4). Nicotine sulfate (40 per cent) with brown sugar (No. 6) or with molasses (No. 8) was equal to the standard tartar emetic spray (No. 2), while with corn sirup (No. 7) the control was slightly lower. The combination of sodium antimony lactophenolate containing antimony equivalent to tartar emetic compared favorably with the best tartar emetic spray when used with brown sugar, corn sirup, or molasses (Nos. 9, 10, 11). The thiocyanate containing 50 per cent beta-thiocyanoethyl ester of aliphatic

Table 1.—Effectiveness of various sprays for control of the gladiolus thrips on gladiolus variety La Paloma in greenhouse. Beltsville, Md., 1942.

MATERIALS IN 100 GALLONS OF SPRAY	TOTAL THRIPS ON 10 PLANTS, NUMBER	REDUCTION IN POPULATION, PER CENT
1. Untreated check	559	0.0
2. Tartar emetic, 2 lbs.; brown sugar, 4 lbs.	25	95.52
3. Tartar emetic, 2 lbs.; corn sirup #1,[1] 3.16 pts.	30	95.27
4. Tartar emetic, 2 lbs.; molasses,[2] 3.16 pts.	21	96.89
5. Tartar emetic, 2 lbs.; corn sirup #2,[1] 3.16 pts.	39	93.66
6. Nicotine sulfate (40%), 1 qt.; brown sugar, 4 lbs.	32	94.92
7. Nicotine sulfate (40%), 1 qt.; corn sirup #1,[1] 3.16 pts.	56	90.62
8. Nicotine sulfate (40%), 1 qt.; molasses,[2] 3.16 pts.	30	95.27
9. Sodium antimony lactophenolate, 8 lbs.; brown sugar, 4 lbs.	20	97.06
10. Sodium antimony lactophenolate, 8 lbs.; corn sirup #1,[1] 3.16 pts.	22	96.35
11. Sodium antimony lactophenolate, 8 lbs.; molasses,[2] 3.16 pts.	28	95.63
12. Thiocyanate #1,[3] 1 qt.; brown sugar, 4 lb.; spreader,[4] 1 qt.	134	76.02
13. Thiocyanate #1,[3] 1 qt.; corn sirup #1,[1] 3.16 pt.; spreader,[4] 1 qt.	159	71.55
14. Thiocyanate #2,[5] 1 pt.; brown sugar, 4 lbs.	58	90.29
15. Thiocyanate #2,[5] 1 pt.; corn sirup #1,[1] 3.16 pts.	120	78.53

[1] Commercial dark-colored corn sirups for table use, No. 1 sweetened with cane sirup, No. 2 sweetened with cane sirup and granulated sugar.
[2] Dark form of New Orleans molasses, for table use.
[3] Contains 50 per cent beta-thiocyanoethyl esters of aliphatic fatty acids averaging 10 to 18 carbon atoms.
[4] Phthalic glyceryl alkyd resin.
[5] Contains 50 per cent lauryl thiocyanate.

fatty acids was considerably less effective when combined with brown sugar or corn sirup and a spreader (Nos. 12, 13), while the thiocyanate containing 50 per cent lauryl thiocyanate approached the effectiveness of tartar emetic when combined with brown sugar (No. 14) but was considerably less effective with corn sirup (No. 15). It should be pointed out that although equal quantities on the basis of weight of all sweetening agents were added to these sprays, less sugar was applied in the corn sirup mixtures and the molasses, whose sugar contents were approximately 60 per cent and 70 per cent respectively.

FIELD EXPERIMENTS.—The corms for the field experiments were planted May 25–27, and beginning June 30 a weekly schedule of six spray applications was followed until August 4, the last being applied after a few flowers had opened, and were cut on July 29 and August 4. Five field experiments were conducted in 1942: (1) Tests with lead arsenate, nicotine sulfate, and paris green with sugar substitutes at dosages considered as giving maximum control on Flaming Sword, a thrips-susceptible variety of gladiolus; (2) tests with nicotine sulfate in combination with reduced quantities of sirups and molasses on Flaming Sword; (3) tests with nicotine sulfate and with reduced quantities of lead arsenate in combination with reduced quantities of commercially available table sirups on Flaming Sword; (4) tests with tartar emetic and nicotine sulfate with corn sirup on La Paloma, a variety moderately resistant to thrips attack; and (5) exploratory tests with miscellaneous new materials or combinations on La Paloma. The experiments were arranged to utilize all available field plantings and yet avoid as much as possible the inclusion of doubtful materials with those that might have immediate application.

Experiment 1.—The main field experiment included lead arsenate (6 lb.) in 6 combinations with brown sugar, molasses, sirups, and honey; nicotine sulfate in 5 combinations with the same molasses, sirups, and honey; paris green in 3 combinations with blackstrap molasses and corn sirup, including the addition of hydrated lime to reduce foliage injury; and tartar emetic with brown sugar as a standard for comparison. Each treatment was replicated 4 times on 50-corm plots of the thrips-susceptible variety Flaming Sword in randomized blocks.

For these tests a cheap blackstrap molasses, as used for stock feed or alcohol production, and corn molasses, a residue from corn sirup manufacture, contained about 70 per cent of sugars. The pure corn sirup contained 18.5 per cent of dextrose, 25 per cent of maltose, and 42 per cent of reducing sugars. The cane sirup (70 per cent sugars), said to be produced by boiling expressed juice of sugarcane to a sirupy consistency, and honey (80 per cent sugars) were standard products as purchased on the market.

The experimental procedure for determining percentages of control was essentially the same as followed by Nelson (1938), except that uninjured flowers were differentiated from those with slight flecking but yet salable according to the opinion of several commercial florists. Data on the number of grade 1 and salable flowers and the per cent control are given in table 2. The per cent control was calculated from Abbott's formulas (1925); $(X-Y)100/X$, where X is the percentage of unsalable flower spikes from the checks and Y is the per cent of unsalable spikes from the treated plot. The rates of control of thrips for 1942 as recorded in the table are somewhat lower than were reported previously for tartar emetic (Nelson 1938; Johnson & Smith 1940), possibly because of excessive rainfall during the period in which sprays were being applied. During this 6-week period a total rainfall of 11.42 inches was recorded, in which rain fell on 14 days, including rain within 48 hours after four of the six applications. In comparison with tartar emetic and brown sugar under these severe conditions, all lead arsenate sprays were less effective, but the sirup and molasses combinations (Nos. 4 to 7) were superior to the combination with brown sugar (No. 3), while corn molasses (No. 8) gave very poor results. Among the nicotine sprays the combination with honey (No. 12) was slightly better than tartar emetic (No. 2) while with corn sirup and cane sirup (Nos. 10, 11) the results were considerably better. The nicotine combination with corn molasses (No. 13) was inferior to tartar emetic, and very little control effects were obtained with blackstrap molasses (No. 9). Paris green with corn sirup (No. 14) was superior to tartar emetic (No. 2), but the addition of hydrated lime greatly reduced the effectiveness (No. 16). The paris green-molasses combination with addition of lime (No. 15) was less effective than tartar emetic, and the lime did not greatly reduce the burning of foliage.

By an analysis of variance of salable flowers it was shown that all treatments except No. 9 (nicotine sulfate and blackstrap molasses) were better than checks; that compared with the tartar emetic-brown sugar sprays as a standard none were better, and Nos. 8, 9, and 16 were inferior. Compared with nicotine sulfate and corn sirup (No. 10) or cane sirup (No. 11), treatments Nos. 3, 6, 8, 9, and 16 were inferior. By analysis of variance of uninjured flowers, all treatments were better than checks except Nos, 3, 8, 9, and 16; compared with tartar emetic-brown sugar (No. 2) treatments Nos. 8, 9, and 16 were inferior, and No. 11 (nicotine sulfate and cane sirup) was better. Compared with nicotine sulfate and corn sirup (No. 10), treatments Nos. 3, 8, 9, and 16 were inferior, and with cane sirup (No. 11) all treatments except Nos. 10 and 13 were inferior.

Experiment 2.—In table 3 are given the results of 6 treatments on each of the two 50-corm plots of the variety Flaming Sword where nicotine sulfate was used with sirup and molasses at concentrations to give sugar contents comparable with that in the tartar emetic spray. In this experiment, where the infestation was evidently heavier than in experiment 1, the salable flowers in the checks being 26.4 per cent and 43.9 per cent, respectively, tartar emetic-brown sugar spray gave somewhat higher control. In comparison with the tartar emetic-brown sugar spray (No. 1), nicotine sulfate with corn sirup (3 qts.) or with cane sirup (2 qts.) (Nos. 12, 13) was less efficient on the thrips-susceptible variety Flaming Sword than when used at the 3-gallon rate in experiment 1. These results indicate that 2 quarts of corn sirup per 100 gallons, as found by Eichmann (1942) and the writer (table 1) to be highly efficient in the greenhouse, cannot be depended upon to be equally efficient in the field. Of interest is the greater efficiency of nicotine sprays containing 2 quarts of blackstrap molasses or of corn molasses (Nos. 9, 14) in table 3 as compared with the same combinations at the 3-gallon rate in experiment 1 (Table 2).

In table 3 are also given results of treatments on the suceptible variety Picardy, where tartar emetic (No. 2) was slightly more effective than sodium antimony lactophenolate (No. 5), both with 2 quarts of blackstrap molasses, and much more effective than nicotine sulfate with 3 gallons of molasses (No. 6). Where sodium benzoate or carbolic acid (88 per cent phenol) was added to the molasses sprays to test the retarding effect of fungus growth on the foliage, an increase in efficiency of the sprays is evident for both

Table 2.—Yield of uninjured flowers and salable flowers, and control of the gladiolus thrips with lead arsenate, nicotine sulfate, and tartar emetic on the gladiolus variety Flaming Sword. Beltsville, Md., 1942.

Material in 100 Gallons of Spray	Total Flowers, Number	Uninjured Flowers, Number	Salable Flowers, Number	Control, Per Cent	Mean Unit Weight of Corms in Grams	
					Planted	Harvested
1. Untreated check	189	11	83	—	17.15	49.1
2. Tartar emetic, 2 lbs.; brown sugar, 4 lbs.	182	60	150	68.6	17.12	42.8
3. Lead arsenate, 6 lbs.; brown sugar, 64 lbs.	194	36	139	49.4	17.15	40.1
4. Lead arsenate, 6 lbs.; blackstrap molasses, 3 gals.	190	46	153	65.2	17.17	30.7
5. Lead arsenate, 6 lbs.; corn sirup, 3 gals.	187	51	145	59.9	17.25	41.7
6. Lead arsenate, 6 lbs.; cane sirup, 3 gals.	188	47	143	57.4	17.20	40.3
7. Lead arsenate, 6 lbs.; honey, 3 gals.	192	58	148	59.2	17.20	44.6
8. Lead arsenate, 6 lbs.; corn molasses, 3 gals.	187	24	112	28.5	17.15	37.9
9. Nicotine sulfate, 1 qt.; blackstrap molasses, 3 gals.	182	12	101	20.7	17.20	45.4
10. Nicotine sulfate, 1 qt.; corn sirup, 3 gals.	191	69	171	81.3	17.12	44.7
11. Nicotine sulfate, 1 qt.; cane sirup, 3 gals.	194	93	171	78.8	17.12	43.3
12. Nicotine sulfate, 1 qt.; honey, 3 gals.	189	51	159	71.7	17.15	47.6
13. Nicotine sulfate, 1 qt.; corn molasses, 3 gals.	192	65	151	61.9	17.15	47.3
14. Paris green, 0.4 lb.; corn sirup, 3 gals.	193	59	166	75.0	17.15	40.4
15. Paris green, 0.4 lb.; blackstrap molasses, 3 gals.; hydrated lime, 0.4 lb.	194	45	150	57.8	17.07	33.7
16. Paris green, 0.4 lb.; corn sirup, 3 gals.; hydrated lime, 0.4 lb.	192	29	114	27.6	17.17	42.1
Minimum significant difference for odds of 19 to 1		28.7	26.7	—	—	6.36

tartar emetic (Nos. 2, 3, 4) and nicotine sulfate (Nos. 6, 7, 8). Nicotine sulfate sprays with 3 gallons of blackstrap molasses (Nos. 7, 8) were apparently no more effective than with 2 quarts of molasses (Nos. 10, 11) with the two preservatives added.

Experiment 3.—In table 4 results are given of tests on each of two 50-corm plots of the variety Flaming Sword with commercial table sirups and molasses in combination with 3 pounds of lead arsenate or with 1 quart of 40 per cent nicotine sulfate per 100 gallons of spray. These sirups, containing approximately 70 per cent of reducing sugars, were used at rates to give nearly the same sugar concentration in the finished spray as is provided by 4 pounds of brown sugar. In comparison with the standard tartar emetic-brown sugar spray, the other treatments in this test were generally decidedly inferior. Nicotine sulfate with commercial light corn sirup (containing granulated sugar) and with maple sirup were superior to the two molasses combinations and the two dark corn sirups which contain cane sirup with some granulated sugar. The best lead arsenate combination was with the light form of New Orleans molasses. In comparison with the results obtained in experiment 1 with nicotine sulfate, the quantities of sirups used in experiment 3 were insufficient to give adequate control on a thrips-susceptible variety.

Experiment 4.—In this test, where the original thrips population on the variety La Paloma was more severe than in the block used in experiment 5, a comparison was made between the effectiveness of

tartar emetic (2 lb.) and 40 per cent nicotine sulfate (1 qt.) when combined with 3 quarts of pure corn sirup. The data in table 5 are summarized from the results obtained on 4 replicated plots of 50 corms each. It will be noted that the nicotine sulfate gave a slightly higher percentage

Table 3.—Yield of salable flowers and control of the gladiolus thrips with tartar emetic, sodium antimony lactophenolate and nicotine sulfate with reduced quantities of sirups and molasses. Beltsville, Md., 1942.

Materials in 100 Gallons of Spray	Yield of Salable Flowers and Control on Variety—			
	Flaming Sword			Picardy
	Total Flower Spikes, Number	Salable Flowers, Per Cent	Control, Per Cent	Salable Flowers, Per Cent
1. Tartar emetic, 2 lbs.; brown sugar, 4 lbs.	80	86.2	81.3	—
2. Tartar emetic, 2 lbs.; blackstrap molasses, 2 qts.	—	—	—	66.2
3. Tartar emetic, 2 lbs.; blackstrap molasses, 2 qts.; sodium benzoate, 0.8 lbs.	—	—	—	82.2
4. Tartar emetic, 2 lbs.; blackstrap molasses, 2 qts.; carbolic acid, 0.8 pt.	—	—	—	73.6
5. Sodium antimony lactophenolate, (8 lbs.); blackstrap molasses, 2 qts.	—	—	—	58.8
6. Nicotine sulfate (40%), 1 qt.; blackstrap molasses, 3 gals.	—	—	—	29.3
7. Nicotine sulfate (40%), 1 qt.; blackstrap molasses, 3 gals.; sodium benzoate, 0.8 lb.	—	—	—	45.2
8. Nicotine sulfate (40%), 1 qt.; blackstrap molasses, 3 gals.; carbolic acid 0.8 pt.	—	—	—	46.5
9. Nicotine sulfate (40%), 1 qt.; blackstrap molasses, 2 qts.	74	75.7	66.9	—
10. Nicotine sulfate (40%), 1 qt.; blackstrap molasses, 2 qts.; sodium benzoate, 0.8 lb.	—	—	—	38.0
11. Nicotine sulfate (40%), 1 qt.; blackstrap molasses, 2 qts.; carbolic acid, 0.8 pt.	—	—	—	74.1
12. Nicotine sulfate (40%), 1 qt.; corn sirup, 3 qts.	83	72.3	62.3	—
13. Nicotine sulfate (40%), 1 qt.; cane sirup, 2 qts.	81	66.7	54.8	—
14. Nicotine sulfate (40%), 1 qt.; corn molasses, 2 qts.	66	90.9	87.6	—
15. Untreated check	68	26.4	—	—

of clean flowers and salable flowers, and the degree of control was slightly higher than for tartar emetic.

Comparisons of the relative efficiency of tartar emetic with brown sugar and with corn sirup in the greenhouse are indicated in table 1, and in the field in tables 5 and 6. Eichmann (1942) also found

Table 4.—Results of field tests with lead arsenate and nicotine sulfate with commercial sirups, as compared with tartar emetic, against the gladiolus thrips on gladiolus variety Flaming Sword. Beltsville, Md., 1942.

Sugar or Sirup (Quantity per 100 Gallons of Spray)	Per Cent Increase in Salable Flowers[1] with—		
	Lead arsenate, 3 lb	Nicotine sulfate, 1 qt.	Tartar emetic, 2 lb
Brown sugar, 4 lbs.	—	—	52.2
Light corn sirup, 2 qts.	0.0	45.3	—
Dark corn sirup, 2 qts.	17.3	23.6	—
Dark corn sirup, 2 qts.	5.9	12.5	—
Light New Orleans molasses, 2 qts.	62.6	22.5	
Dark New Orleans molasses, 2 qts.	12.7	26.8	
Maple sirup, 2 qts.	0.0	46.2	

[1] 43.3 per cent of salable flowers occurred in untreated check plots.

corn sirup and brown sugar with tartar emetic to be equally effective against the onion thrips. While a direct comparison cannot be made, there is no indication that the efficiency of the nicotine-corn sirup combination (Table 5) is increased by the addition of oxidized corn starch (No. 12 in table 6).

Experiment 5.—In table 6 are given the results of tests with several miscellaneous materials, including adjuncts with tartar emetic, and several possible toxic materials with brown sugar, paris green with buffers to reduce spray injury, and nicotine sulfate with an oxidized corn starch, suggested as possibly increasing the residual qualities. Each treatment was applied to two 50-corm plots of the moderately thrips-resistant variety La Paloma. The comparisons were made on the

Table 5.—Yield of clean flowers and salable flowers on variety La Paloma obtained with tartar emetic and nicotine sulfate with corn sirup. Beltsville, Md., 1942.

Materials in 100 Gallons of Spray	Clean Flowers		Salable Flowers		Control, per Cent
	Number	Per Cent	Number	Per Cent	
Tartar emetic, 2 lb.; corn sirup, 3 qt.	153	65.9	213	91.8	88.8
40% nicotine sulfate, 1 qt.; corn sirup, 3 qt.	145	67.4	201	93.5	91.1
Untreated check	4	2.2	44	26.7	—

basis of clean rather than salable flowers, since 75.7 per cent of those on untreated plots were considered salable. The sugar sorbitol (No. 2) and the substitute isoamyl salicylate (No. 3) in combination with tartar emetic gave no promising indication of control, nor did the lauryl thiocyanate (No. 4) which was relatively effective in the greenhouse (see table 1),

Table 6.—Yield of clean flowers and control obtained from different spray combinations on gladiolus variety La Paloma. Beltsville, Md., 1942.

Materials in 100 Gallons of Spray	Thrips-free Flowers		Control Per Cent
	Number	Per Cent	
1. Tartar emetic, 2 lbs.; brown sugar, 4 lbs.	118	88.1	79.4
2. Tartar emetic, 2 lbs.; sorbitol, 2 gals.	52	47.7	9.3
3. Tartar emetic, 2 lbs.; isoamyl salicylate, 500 c.c.	57	53.8	19.9
4. Lauryl thiocyanate, 1 pt.; brown sugar, 4 lbs.	46	40.4	—
5. Xanthone, 3 lbs.; brown sugar, 4 lbs.	40	35.4	—
6. Phenothiazene, 3 lbs.; brown sugar, 4 lbs.	62	56.9	25.3
7. Paris green, 6.31 oz.; corn sirup, 3 qts.	72	67.9	46.1
8. Paris green, 6.31 oz.; blackstrap molasses, 2 qts.	97	84.3	72.8
9. Paris green, 6.31 oz.; blackstrap molasses, 2 qts.; magnesium hydroxide, 6.31 oz.	73	70.2	48.4
10. Paris green, 6.31 oz.; blackstrap molasses, 2 qts.; hydrated lime, 6.31 oz.	84	61.2	32.8
11. Nicotine sulfate, 1 qt.; blackstrap molasses, 2 qts.; starch, 2 lbs.	98	85.2	74.4
12. Nicotine sulfate, 1 qt.; corn sirup, 3 qts.; starch, 2 lbs.	89	87.2	77.8
13. Untreated check	47	42.3	—

nor xanthone (No. 5) nor phenothiazene (No. 6), all combined with brown sugar. Paris green with pure corn sirup (No. 7) was relatively ineffective, while with blackstrap molasses (No. 8) the control approximated that with tartar emetic and brown sugar. Addition of magnesium-oxide or hydrated lime to the paris green-molasses sprays (Nos. 9, 10) greatly reduced their efficiency. Nicotine sulfate with molasses or corn sirup with the addition of an oxidized corn starch (Nos. 11, 12) gave approximately the same control as the standard tartar emetic-brown sugar spray. It will be noted that the corn sirups containing 42 per cent reducing sugars and the molasses containing 70 per cent sugars were used in quantities to give approximately the same sugar concentrations as were provided by the brown sugar.

SODIUM ANTIMONY LACTOPHENOLATE.—According to unpublished results of experiments by D. J. De Coursey, sodium antinomy lactophenolate, a liquid that contains one-fourth as much antimony (by weight) as does tartar emetic, was tested in 1941 on gladiolus along with tartar emetic. Tartar emetic (2 lbs.) with brown sugar (4 lbs.) or white sugar (4 lbs.) and sodium antimony lactophenolate (8 lbs.) with brown sugar (4 lbs.) were approximately equally effective. The latter material at the 8-pound rate with white sugar (4 lbs.) or at the 4-pound rate with brown sugar (4 lbs.) was inferior on the thrips-susceptible variety Joe Coleman. In the greenhouse tests conducted in 1942, the antimony compounds were approximately equal in efficiency when used with brown sugar, corn sirup, or dark table molasses (Table 1), but in field tests on the susceptible variety Picardy, comparing tartar emetic (2 lbs.) or sodium antimony lactophenolate (8 lbs.) with blackstrap molasses (2 qts.), the percentages of salable flowers were 66.2 and 58.8, respectively (Table 3).

EFFECTS OF SPRAYS ON PLANTS.—Richardson (1934) and Eichmann (1942) mentioned the development of fungi attacking the molasses sprays that left a black sooty deposit. In the greenhouse test of 1942 (Table 1) this deposit was absent on foliage sprayed with molasses in combination with sodium antimony lactophenolate and was conspicuous on similar molasses sprays containing nicotine sulfate or tartar emetic. In further field tests (Table 3) in 1942 that included blackstrap molasses, sooty fungus was absent on foliage sprayed with sodium antimony lactophenolate or lead arsenate and was practically absent where sodium benzoate was added to the nicotine sulfate or tartar emetic sprays. Carbolic acid added to the two latter sprays did not perceptibly reduce the sooty deposit.

Tartar emetic in combination with brown sugar, blackstrap molasses, or corn sirups caused no direct injury to the foliage of gladiolus, but when applied to flower buds showing color the unopened petals were injured. In experiment 5 the only adjunct with tartar emetic that caused injury was isoamyl salicylate. Tips and surface of young leaves were browned by the first two applications of this combination.

Lead arsenate at the 6-pound rate (experiment 1) in combination with 3 gallons

of corn sirup or of honey caused slight marginal burning of foliage and little or no reduction in number of cormels, while combinations with brown sugar (64 lbs.), or 3 gallons of blackstrap molasses, of cane sirup, or of corn molasses caused severe foliage injury and evident reduction in size and quality of corms, with few or no cormels. In experiment 1 the analysis on mean unit weight of harvested corms showed that increase in weight over that of planted corms was less than in the checks when lead arsenate was used with all sugars and sirups except with honey. In other tests where lead arsenate at the 3-pound rate was used with 2 quarts of molasses, foliage injury was evident but less severe than that discussed above. Lead arsenate left a white deposit on sprayed plants in all treatments and was more conspicuous with the heavier 6-pound dosage.

In experiment 1, paris green sprays with corn sirup (3 gal.) caused moderately severe burning of foliage on Flaming Sword and reduced cormel production to few or none. While addition of hydrated lime almost entirely eliminated foliage injury and reduction of cormel production, it did not prevent severe foliage injury when molasses (3 gallons) was used. The mean unit weight of harvested corms showed that weight increase was significantly lower than in the checks in all paris green treatments. In experiment 5 the same quantity of paris green caused only slight foliage injury on the variety La Paloma when combined with 3 quarts or corn sirup or with 2 quarts of blackstrap molasses. Addition of hydrated lime or magnesium hydroxide to the latter spray prevented plant injury but greatly reduced the effectiveness against the thrips.

Nicotine sulfate in combination with all sirups and molasses tested caused no evident foliage or flower injury and did not appreciably reduce the number of cormels or significantly reduce the mean unit weight of harvested corms over checks in experiment 1 (table 2). The foliage sprayed with combinations containing corn sirup, cane sirup, or honey was much cleaner in appearance than where blackstrap molasses or corn molasses was used, even with addition of the preservative sodium benzoate.

DISCUSSION.—The effectiveness of tartar emetic with corn sirup and other sirups and molasses appears equal to that of the standard tartar emetic-brown sugar spray, and the substitute sugars may be used as long as this poison is available. The more bulky and more expensive sodium antimony lactophenolate is another alternative poison. Since tartar emetic is now apparently available in small quantities for insecticidal sprays, further tests are needed to determine the quantity of sirups required to control thrips on thrips-susceptible varieties.

In the present investigations of possible substitutes for tartar emetic and brown sugar the most interesting finding was the greater effectiveness of nicotine sulfate when combined with corn sirup, cane sirup, or honey than when combined with blackstrap molasses, which was selected by previous workers because of its low cost. While applying sprays containing nicotine and table molasses or blackstrap molasses the operators were made very uncomfortable because of the strong nicotine odors, which were not in evidence with the other sirup or honey combinations. Apparently the low pH of molasses is not the primary cause for the evolution of nicotine, since that of honey is slightly lower. The problem deserves further study, which may reveal causes for the shortness of the period of residual action of nicotine-molasses sprays. Further studies should be made to determine the minimum effective concentration of sirups in nicotine sprays for use on thrips-susceptible varieties under various weather conditions. The tests with lead arsenate in various combinations appeared to offer no substitute equal to the thripicidal action and safety to plants offered by the nicotine or the two antimony compounds.

The highly effective combinations of paris green (0.4 lb.) with 3 gallons of corn sirup or 2 quarts of molasses caused less foliage injury than other combinations and gave evidence that a fairly satisfactory combination might be developed with this poison.

SUMMARY.—In greenhouse and field experiments to control the gladiolus thrips during 1942, tartar emetic (2 lbs.) with brown sugar (4 lbs.) was equal in effectiveness to other combinations with corn sirup, cane molasses, or blackstrap molasses diluted to give similar sugar contents in the finished spray. Sodium an-

timony lactophenolate (8 lbs.) with the same materials was equal or nearly so in effectiveness.

One quart of 40 per cent nicotine sulfate in combination with 3 gallons of corn sirup or cane sirup per 100 gallons of spray on a thrips-susceptible variety of gladiolus was more effective than tartar emetic, while 3 quarts of corn sirup with nicotine appeared adequate to protect a moderately resistant variety. Maple sirup and honey were also highly effective. Minimum effective concentrations for all sirups have not been established. Nicotine sulfate combined with blackstrap molasses or corn molasses gave poor control. The sprays containing blackstrap molasses or cane molasses apparently caused rapid evolution of nicotine fumes, which loss possibly decreased the residual action of the nicotine.

Combinations of lead aresenate with brown sugar, sirups, and molasses were less effective than tartar emetic or nicotine sulfate. In addition they injured the foliage and flower petals showing color, as well as causing variable injury to the foliage and reduction in normal increase of corms.

Paris green (0.4 lb.) combined with 3 gallons of corn sirup or 2 quarts of blackstrap molasses was highly effective and caused less injury than did combinations with larger quantities of molasses. The addition of hydrated lime or of magnesium hydroxide to paris green sprays reduced foliage injury but also the effectiveness against the thrips.

Sorbitol and isoamyl salicylate tested as substitutes for sugar, and xanthone, phenothiazene, and two thiocyanates tested as substitutes for tartar emetic, were ineffective.

Black sooty fungus developed on foliage sprayed with combinations of nicotine sulfate or tartar emetic and black strap molasses, but not with the combination sodium antimony lactophenolate and the same molasses. Addition of sodium benzoate (0.8 lb. per 100 gallons) to the nicotine or tartar emetic sprays prevented fungus growth.—1-4-43.

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HORTICULTURAL INSPECTION NOTES

The Chief of the Bureau of Entomology and Plant Quarantine in administrative instructions (circular B.E.P.Q. 485, 12th revision) gave notice that effective June 16, 1943, the certification requirements of the white-fringed beetle quarantine regulations as modified effective December 28, 1942, in the 11th revision of the above circular, shall remain in effect until further modified or revoked.

The Connecticut statute concerning shipments of nursery stock from other States was amended effective March 16, 1943, eliminating the requirement that out-of-State nurserymen must file their certificate of inspection and apply for a permit. All that is required under the current regulations is that a valid copy of the certificate of inspection of the state of origin be attached to each lot of nursery stock entering Connecticut.

The California oriental fruit moth quarantine regulation (No. 7) pertaining to infestations within the State as revised and amended in June 1943, has for its principal changes the enlargement of the infested territory, the addition of loquat fruits to the host list, and provision for fumigation of host fruits and for steam sterilization of boxes.

The Influence of Fungicidal Sprays on Entomogenous Fungi and on the Purple Scale in Florida

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The Florida climate is favorable to the growth of entomogenous fungi. Frequent showers during the rainy season aid in disseminating the fungus spores, and the warm, humid weather in this season is ideal for the germination and growth of fungi. Many species of scales and whiteflies can be found infected with fungi throughout the important citrus-growing areas of the state.

A survey of published investigations and verbal reports on the problem of the relationship of fungicidal sprays to entomogenous fungi has revealed a diversity of opinion as to the cause of the scale increase which follows the use of a fungicide. Some believe that the elimination of the fungi is the major factor; others, that the inert granular residue contained in the spray is the most important factor; and still others, that the increase is the result if the combination of the two factors.

Rolfs & Fawcett (1908) cited the harmful results which followed the use of bordeaux mixture. The fungicide destroyed the fungi that killed the scale, and an increase in scale numbers resulted.

In the earlier days of road construction in Florida many clay- or shell-surfaced roads were built, and it was a matter of common knowledge that the trees bordering such roads were more heavily infested with scales than were trees of the same grove farther removed from the road. Road dust and inert granular residue from sprays were in time proved to be a definite factor in scale increase.

When Thompson (1935) applied hydrated lime to citrus trees, a noticeable scale increase resulted. The same author (1938), summarizing a series of experiments on various residue-leaving sprays, found that the residue inhibited the growth of entomogenous fungi and brought about more suitable conditions for increase in scale populations.

Osburn & Spencer (1938), in a series of experiments on adhesives for sulfur sprays, showed that the increase of the purple scale was directly proportional to the amount of inert residue contained in the spray, and to the number of applications.

The Division of Foreign Parasite Introduction, in cooperation with the Division of Fruit Insect Investigations, of the Bureau of Entomology and Plant Quarantine conducted an experiment to determine the influence of fungicidal sprays on entomogenous fungi and on purple scale populations. The experimental grove was in Orange County, Fla. The work was begun in 1938 and completed in 1939. The present paper is a brief report of this experiment.

Sources of Samples.—The purple scale is found on both the wood and leaves of citrus trees. The scales on the wood, however, are accumulative over a longer period than those on the leaves. Since it was desirable to obtain samples that would be representative of current conditions over the whole tree, leaves about 18 months old or less were selected.

These leaf samples were collected from a restricted portion of the tree. Leaves innermost on the branches had the oldest populations, and the stages were mostly dead scales and matured females. The outermost leaves, consisting of spring flush growth, had newly attached scales and crawlers. Leaves in the intermediate area bore a good proportion of all stages. Samples taken at random inward on the branches, but adjacent to spring flush growth, contained a few of the oldest and a few of the youngest leaves but for the most part were made up of leaves intermediate in age. Accordingly, leaves from this middle area were selected as the most representative.

Data Obtained from Samples.—Counts of scales on the leaves were made with the aid of a binocular microscope. The populations were recorded and classified as follows: (1) All living, dead, and parasitized stages (total infestation); (2) dead stages showing no evidence of fungi; (3) dead stages showing evidence of fungi (mortality associated with fungi); (4) all

[1] Constructive criticisms and advice were received from F. M. Wadley and L. B. Reed.

dead stages (total mortality); and (5) the remainder, all apparently living stages.

In order that any variability due to individual judgment during microscopical examination might be reduced, the leaves of each sample were distributed equally between two observers.

EXPERIMENTAL PROCEDURE.—The experiment was conducted on Parson Brown orange trees. Each plot contained a single tree, and each treatment was tested on five plots.

A sample of 14 leaves taken from each tree was collected and examined in 1938 from August 22 to 29 and in 1939 from August 14 to 19.

The treatments were classified into 2 levels of inert residue and 2 levels of copper. The low-residue level included unsprayed check plots and the plots receiving ammoniacal copper. In this level the residues resulted from accumulated grove dust and the small amount of residue contained in the ammoniacal copper spray. In the high-residue level the plots, in addition to grove dust, received spray materials containing 6 pounds of hydrated lime per 100 gallons of water. The 2 levels of copper were studied by comparing the plots to which no copper was applied with those receiving sprays containing copper. The sprays were applied on April 20 and July 8.

The following quantities of spray materials are per 100 gallons of water:

Copper absent:
Low residue...Check, unsprayed.
High residue..Aluminum sulfate 6 pounds and hydrated lime 6 pounds.

Copper present:
Low residue...Cupric carbonate 1 pound and ammonia 9 pints.
High residue..Copper sulfate 6 pounds and hydrated lime 6 pounds (bordeaux 6-6-100).

Table 1.—Total infestation of the purple scale resulting after the use of sprays with 2 levels of inert residue and 2 levels of copper. 1938.

LEVELS OF RESIDUE	LIVING AND DEAD SCALES		
	Copper Absent	Copper Present	Total
	Number	*Number*	*Number*
Low	1,420	1,848	3,268
High	7,686	5,793	13,479
Total	9,106	7,641	

Significant difference at 5 per cent level, 7,443.

TOTAL INFESTATION.—A summary of the total numbers of living and dead scales is given in table 1. The only significant difference in total infestation was between the two levels of inert residue. Plots treated with sprays of high-residue content had high total infestations of scales. There was no significant difference in total infestation between the two levels of copper.

High total infestations were associated with the high-residue content of the sprays and not with the fungicidal properties of the sprays.

MORTALITY ASSOCIATED WITH FUNGI.—All stages of scales showing evidence of infection by fungi were classified under mortality associated with fungi. This term was used in preference to a term which would have implied that the fungi were highly parasitic. The results of the experiments indicated that the numbers of scales infected by fungi had no related influence on total mortality. Percentages of total infestation of the scale were used to compare the rate of mortality associated with fungi and total mortality. As the numbers of dead scales were highly correlated with the population densities they were converted into percentages, thereby furnishing comparisons independent of density.

Table 2.—Mortality associated with fungi after the use of sprays with 2 levels of residue and 2 levels of copper. 1938.

LEVELS OF RESIDUE	MORTALITY ASSOCIATED WITH FUNGI		
	Copper Absent	Copper Present	Average
	Per Cent	*Per Cent*	*Per Cent*
Low	32	0.6	16.3
High	14	.0	7.0
Average	23	0.3	

The records on mortality associated with fungi are entered in table 2. The fungicidal, or copper, sprays practically eliminated the infection of the scale by entomogenous fungi. The absence of fungi within each level of residue did not cause any measurable influence on total infestation, as is shown in table 1. Between the two treatments in which copper was present or absent in the low level of residue there was a difference of 31.4 per cent in

mortality associated with fungi and a small difference of 8 per cent in total mortality. (For total mortality see table 3.) Between the same treatment classification in the high level of residue there was a difference of 14 per cent in mortality associated with fungi and a difference of 1 per cent in total mortality. The total mortality within each level of residue was not significantly influenced by differences in the numbers of scales infected by fungi. Therefore the difference in total mortality between the two levels of residue was dependent on factors other than the mortality associated with fungi. It would seem, however, that the fungus population was, to a certain extent, dependent on scale mortality. In the two treatments that did not include copper the higher percentage of scale infected by fungi was associated with the higher rate of mortality. The scarcity of fungi in the aluminum-and-lime treatment would seem to be the result of a smaller population of dead or weakened scales susceptible to the fungi.

TOTAL MORTALITY.—The data on the rate of total mortality are contained in table 3. The only significant mean difference is between the levels of residue. The

Table 3.—Percentage of total mortality of the purple scale after the use of sprays with 2 levels of inert residue and 2 levels of copper. 1938.

LEVELS OF RESIDUE	TOTAL MORTALITY		
	Copper Absent	Copper Present	Average
	Per Cent	*Per Cent*	*Per Cent*
Low	83	75	79
High	58	57	58
Average	71	66	

Significant difference at 1 per cent level, 11.

scarcity or abundance of entomogenous fungi did not have a significant influence on the rate of mortality between the two levels of copper (presence or absence). The significant difference in total mortality between the two levels of inert residue is associated with a pronounced difference in total infestation, as an increase in scale population and a lower rate of mortality occurred in the treatments with residue applications (Tables 1 and 3).

TOTAL INFESTATION 1 YEAR LATER.—There were no further spray applications after July 1938, but the experiment was kept under observation during 1939.

The data on the total infestation are entered in table 4. The significant difference was between the total infestation at the two levels of residue.

Table 4.—Total purple scale infestation in 1939 resulting from sprays having 2 levels of residue and 2 levels of copper applied the previous year.

LEVELS OF RESIDUE	TOTAL LIVING AND DEAD SCALES		
	Copper Absent	Copper Present	Total
	Number	*Number*	*Number*
Low	663	1,681	2,344
High	3,614	2,643	6,257
Total	4,277	4,324	

Significant difference at 1 per cent level, 3,353.

The reduction in infestation during the year (Tables 1 and 4) could be attributed to two causes. A heavy leaf fall occurred during the winter months in the treatments with the high inert-residue sprays. The heavily infested leaves constituted a major portion of the leaf drop. There was also an abnormally high rainfall during the summer months, which washed most of the inert residue from the remaining leaves.

The use of copper, which practically eliminated infection of the scale by fungi the previous year, had no influence on the total scale infestation the following year.

EFFECT OF FUNGUS INOCULATION ON INFECTION.—A spray of fungus spores suspended in water was applied in July 1938 to five trees that had received no chemical spray treatments during that season. This treatment was applied to see if the infection of the purple scale by the fungi could be increased, and if an increase was in any way associated with an increase in the rate of mortality when compared with that of five trees that did not receive the spore spray. Spores of the pink scale fungus, *Nectoria diploae* B. & C., and the red-headed scale fungus, *Sphaerostilbe aurantiicola* (B. & Br.) Petch, two of the species deemed most important, were used to prepare the suspension.

During the rainy season of 1938 the total rainfall, as well as the frequency with which the showers occurred, was below normal. In 1939 there was an excess of

rain, and the showers occurred almost daily. The rainfall in April averaged 150 per cent of normal, and in August it was the third highest on record as reported by Bennett (1939) in the United States Weather Bureau records.

The percentage of mortality associated with fungi and the percentage of total mortality were observed and recorded for 1938 and 1939. The results of mortality associated with fungi are entered in table 5. There was no significant increase in the percentage of the scale infected by fungi in the spore-sprayed trees; nor was there any difference between the two years, one of which had a high and consistent rainfall, a condition very favorable for the growth of entomogenous fungi.

Table 5.—Difference in mortality of the purple scale associated with fungi between trees receiving a spore spray and unsprayed trees and between a dry (1938) and a wet (1939) season.

Year	Mortality of Scales on—		
	Unsprayed Trees	Sprayed Trees	Average
	Per Cent	*Per Cent*	*Per Cent*
1938	32	39	35
1939	36	38	37
Average	34	39	

Morrill & Black (1912) obtained similar results when they attempted to increase the efficiency of the whitefly fungi. An application of fungus spores would introduce the fungi to groves in which it did not exist, but the efficiency could not be increased by an application of spores in groves having the fungi already present.

The total mortality is summarized in table 6. A significant increase in the percentage of total mortality was associated with the rainy year of 1939. No significant difference in mortality was associated with fungi, therefore it may be assumed that the 9.5 per cent increase in total mortality was the result of conditions other than the influence of fungi.

In the presence of inert residue more scales successfully attach themselves and have a greater vitality. Variations in rainfall could cause variations in the accumulation of inert deposits on the foliage. Frequent and heavy showers should be unfavorable for the accumulation of dust on the leaves, and this may in part account for the increased rate of mortality during 1939.

CONCLUSION.—The use of copper fungicidal sprays decreases the infection of the purple scale by entomogenous fungi. The scarcity or abundance of fungi does not influence the rate of total mortality, nor is any abnormal scale increase associated with the fungicidal properties of the sprays.

The use of sprays containing inert granular residue materials, whether or not these sprays contain copper, causes abnormale purple scale increase and decreases the rate of mortality.

The most important factor causing abnormal purple scale increase following the use of fungicidal sprays is the inert granular residue content of the sprays.

SUMMARY.—In Florida it is possible to find many species of scale insects and whiteflies infected by entomogenous fungi. The climate throughout the citrus-growing areas is favorable to the growth of these fungi on citrus pests.

Table 6.—Difference in the total mortality of the purple scale between trees receiving a spore spray and unsprayed trees and between a wet (1938) and a dry (1939) season.

Year	Mortality of Scales on—[1]		
	Unsprayed Trees	Sprayed Trees	Average
	Per Cent	*Per Cent*	*Per Cent*
1938	83	89	86.0
1939	97	94	95.5
Average	90	91.5	

[1] Least significant mean difference at 1 per cent level, 8.

A survey of the published investigations and verbal reports on the problem of the relationship of fungicidal sprays to the effectiveness of entomogenous fungi revealed a diversity of opinion. Some investigators believed that the elimination of the entomogenous fungi caused scale increase, others that the inert residue was the most important factor, and still others that the increase was due to both factors.

Some of the first improved roads in Florida were shell- or clay-surfaced. Trees bordering such roads were more heavily infested with scales than were trees of the same grove which were farther removed from the road. Road dust and sprays con-

taining inert granular residue materials were in time recognized as important factors causing scale increase.

In an experiment designed to contrast the influence of inert residues and fungicides on the purple scale and entomogenous fungi, it was found that the inert residue contained in the sprays was the more important factor causing scale increase. The fungicides reduced infection of the scale by the entomogenous fungi, but the reduction caused no significant difference in the percentage of total scale mortality or in the total infestation. The percentage of total mortality was lower in both high-residue treatments. There was no difference in the percentage of total mortality between the two high-residue treatments, one of which contained copper.

One year after the sprays had been applied there was no significant difference in total infestation which could be attributed to the use of copper sprays. The two high-residue treatments still had the highest total infestation, but there was a reduction over the previous year. The two main factors of reduction were the dropping of heavily infested leaves and the removal of the spray residue from the trees by rains.

No increase in the percentage of scale infection by entomogenous fungi was obtained by applying a spray of fungus spores.—12-12-42.

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Influence of Moisture and Field Dust on the Susceptibility of the California Red Scale to HCN

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The California red scale, *Aonidiella aurantii* (Mask.), on citrus in southern California is fumigated under tents, generally during the night. Frequently there is a heavy dew on the trees, and a film of water covers many scales. Quayle (1938) says: "It has been observed in the field and also shown in the laboratory that an excess of moisture over the insects decreases fumigation results." In spite of the moisture, good kills are frequently observed in treatments under these conditions, but the kills are usually attributed to increased concentrations resulting from the increased tightness of the tent fabric when damp. In southern California it also has been observed by many that a heavier population of red scales is found on trees next to roads than is found in the interior sections of groves. This is frequently attributed to the presence of increased quantities of "road dust" on the trees adjoining roads. This study includes a series of laboratory tests on the influence of moisture and "field dust" over the scales on their susceptibility to hydrocyanic acid vapor.

EXPERIMENTAL PROCEDURE.—A film of water over the surface of scale-infested lemon fruits was obtained in the laboratory by applying distilled water with an atomizer, by immersing the scale-infested fruits in water, or by permitting dew to collect on them, but usually the first method was used. No spreader was used. With the first two methods the water film was applied immediately before the fumigation was made. On the slightly wet fruits the water film was very thin and formed visible droplets only when the surface was rubbed, but on the very wet fruits large droplets were present.

Scale-infested lemon fruits were dusted with orchard soil that passed through a 200-mesh screen. To get the dust to adhere, the fruits were first sprayed with

water and then dusted by passing compressed air through a chamber containing the fine soil. The dusting was done on the night before fumigation so that the dusted lemons would be dry prior to fumigation. The lightly dusted fruits were comparable to the dustiest in the field, but on those heavily dusted many of the scales were completely concealed.

Red scales relatively resistant to hydrocyanic acid which were on lemon fruits infested in the laboratory were used. The insects were reared in the laboratory, usually at a constant temperature of 77° F. and a relative humidity of 65 per cent. The methods of rearing and treatment were the same as those described by Yust *et al.* (1942). Unless otherwise stated, the scales were fumigated for 40 minutes with decreasing concentrations of hydrocyanic acid gas simulating those obtained in the field. In fumigations at 59° F. the scales were preconditioned and postconditioned for 4 hours at the treatment temperature.

Table 1.—Mortality of second-molt and mature female California red scales fumigated with hydrocyanic acid gas at 77° and 59° F. with various conditions of the lemon fruit surface.

Condition of Lemon Fruits	Mortality, Per Cent			
	Second Molt		Mature Female	
	77° F.	59° F.	77° F.	59° F.
Dry	89.2	96.9	67.6	72.2
Slightly wet	96.1	99.2	85.7	87.2
Very wet	97.9	99.2	94.2	92.4
Very wet and lightly dusted	98.2	98.4	94.1	91.0
Lightly dusted	88.7	95.5	63.8	60.3
Heavily dusted	87.1	96.3	68.1	62.9

The data were analyzed by appropriate statistical methods. Differences likely to be exceeded by chance once in at least 20 times were considered significant.

MORTALITIES ON DRY, WET, AND DUSTED FRUITS.—Six groups of second-molt and mature female scales located on fruits, each group with a different surface condition, were fumigated at 77° and 59° F. with decreasing concentrations of gas. The second-molt scales were fumigated at 77° with concentrations ranging from 2.52 mg. per liter at the beginning to 0.36 mg. at the end and at 59° with concentrations ranging from 1.44 to 0.22 mg. The mature females were treated at 77° with concentrations ranging from 0.94 to 0.14 mg. and at 59° with concentrations ranging from 0.45 to 0.08 mg. Each stage was fumigated at both temperatures on the same day, and the fumigations of each stage at each temperature were replicated on 4 successive days. The second-molt scales were 20 days old, and the mature females were 35 days old. The mortality figures for each stage at each temperature are based on 1,200 insects. The conditions of the fruit surface and the results are given in table 1.

Significantly better kills were obtained on wet than on dry fruits in each test regardless of whether they were clean or dusted. The amount of water on the surface influenced the kill of the mature female scales but not the kill of the second-molt scales, and moisture influenced the kill less at 59° F. than at 77°. There was a tendency for lower kills on dusted, dry fruits than on clean, dry fruits, but the kill on the former was significantly lower than the kill on the latter in only the treatment of the mature female scales at 59°. The amount of dust was unimportant in these tests.

The influence of deposits of dew was also observed. The scales were reared in the laboratory at fluctuating temperatures. Mature female scales on 48 lemon fruits were placed on a table in the yard near the laboratory building. Half of the fruits were covered with wax-impregnated muslin to keep them dry and the remaining half were exposed so dew could collect on them. The wet and dry groups were fumigated simultaneously during the night at an outdoor temperature of 61° F. with a decreasing concentration ranging from 1.73 mg. per liter at the beginning to 0.07 mg. at the end. Immediately prior to and after fumigation the scales were held at outdoor temperatures, so the tests are similar to field fumigations. The kill on dry and wet fruits was 96.3 and 99.3 per cent, respectively, showing a significantly higher kill of wet than of dry scales. Each mortality figure is based on 1200 insects.

The mortality of scales on fruits that had been immersed in water was compared with that on dry fruits. Very little water remained on the immersed fruits, and it was almost entirely restricted to small droplets over the insects. Again, a significantly better kill was obtained on

wet than on dry fruits, but the difference was less than in previous experiments, probably because there was less water on the fruit.

TIME REQUIRED FOR MOISTURE TO INFLUENCE MORTALITY.—Second-molt scales were exposed for 10, 20, 40, and 60 minutes at 77° F. to constant concentrations giving approximately 75 to 96 per cent kill. In each exposure there were 12 dry and 12 wet fruits, 600 scales being included in each group. Detailed information on the treatments used and the results obtained are given in table 2.

In 10-minute exposures moisture increased the kill obtained in fumigations with hydrocyanic acid gas as well as in 20-, 40-, and 60-minute exposures.

INFLUENCE OF MOISTURE ON PROTECTIVE STUPEFACTION.—Gray and Kirkpatrick (1929) observed that prefumigation with a relatively low concentration of hydrocyanic acid prior to fumigation with a normally lethal concentration reduced the kill. The effect was called "protective stupefaction." To determine the influence of moisture when protective stupefaction exists, mature female scales on dry and very wet fruits were prefumigated for 8 minutes with a concentration

Table 2.—The influence of moisture on the kill of second-molt California red scales in 10-, 20-, 40-, and 60-minute exposures to hydrocyanic acid gas.

LENGTH OF EXPOSURE, MINUTES	CONCENTRATION, MG. PER LITER	MORTALITY, PER CENT	
		Dry	Wet
10	2.61	86.5	95.7
20	1.58	76.7	93.7
40	0.94	75.7	93.2
60	0.73	74.7	85.8

of 0.14 mg. per liter and immediately afterward these two groups, and mature female scales on wet and dry fruits not prefumigated, were fumigated simultaneously with a constant concentration of 0.6 mg. at 77° F. The treatment was duplicated, and each mortality figure is based on 900 insects. The results are presented in table 3.

There was protective stupefaction of scales on both wet and dry fruits, but a significantly better kill was obtained on wet fruits than on dry whether or not protective stupefaction occurred. These results were verified in another similar experiment.

DISCUSSION.—This study does not indicate the reason for a higher kill of red scales on wet than on dry fruits. At first it appeared likely that the increased kill on the wet fruits was due to post-exposure fumigation resulting from cyanide gas

Table 3.—Effect of prefumigation with hydrocyanic acid gas on the kill of mature female California red scales on wet and dry fruits.

TREATMENT	MORTALITY, PER CENT	
	Dry	Wet
Final fumigation only	74.8	90.0
Prefumigation and final fumigation	44.2	59.8

given off from water remaining on the fruits after the 40-minute exposure. This explanation was not completely satisfactory because there was an increase in kill on slightly wet fruits that appeared to be dry at the end of the 40-minute exposure (Table 1). However, post-exposure fumigation may explain how the amount of water influenced the kill in certain of the above tests.

In the tests using decreasing concentrations the concentration of gas fell off rapidly after the first 2 minutes. In these treatments it seemed possible that absorbed gas might be given off by the water during the remainder of the exposure period, the concentration being thereby sustained at a higher level near the insect than in the surrounding atmosphere. This explanation was not adequate, because with constant concentrations better kills were obtained on wet than on dry fruits.

In precision measurements of temperature with thermocouples[1] it was shown that, on the average, evaporation of the water decreased the temperature of the insects about 5 Fahrenheit degrees, but according to Quayle and Rohrbaugh (1934) a small drop in temperature during fumigation does not increase the kill. This is verified by tests performed by the authors.

SUMMARY.—The influence of moisture and field dust on the susceptibility of the California red scale to fumigation with hydrocyanic acid vapor was observed in tests conducted in the laboratory under

[1] The temperature measurements were made by F. Munger.

controlled conditions. Higher kills were obtained on wet than on dry lemon fruits regardless of the method of application of the water. Moisture increased the kill in exposures ranging from 10 to 60 minutes, in exposures to constant and decreasing concentrations of the gas, and in exposures in which there was protective stupefaction. Slightly better kills were obtained on clean than on dusty lemon fruits in certain of the tests made.—1-2-43.

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Control of the Sugarcane Borer in Puerto Rico by Laboratory-Reared Parasites.

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For that most insidious pest of sugarcane, sugercane borer, *Diatraea saccharalis* F., no method of chemical or cultural control gives the least promise of commercial value. Other insect pests of sugarcane have been, and are, commercially controlled by their natural enemies, as the leafhopper of Hawaii by its insect parasites and predators, and white grubs in Puerto Rico by the giant toad, and control by its natural enemies seems the most hopeful line of attack on the moth borer. In addition to the parasites already present in Puerto Rico, several others are known to exist in other cane-growing countries, but, to date, their importation and colonization here has not been an outstanding success.

The one remaining possibility would appear to be to determine what can be done to favor native parasites to increase their abundance and effectiveness. Years ago, it was shown that less borer damage occurs in ratoon cane of which the trash was not burned in harvesting the preceding crop, and for that reason the nonburning of cane trash is standard practise in Puerto Rico. For a more positive method of control it has been suggested that parasites could be reared in the laboratory and released when and where needed, as has been done on a commercial scale in Peru and Barbados, and experimentally in Louisiana. Both Peru and Louisiana have definite winter seasons, during which the egg-parasites of the borer almost or entirely disappear from cane fields. Thus, in the spring, the first two or three generations of the borer are practically free from attack by parasites, and their caterpillars become very abundant and cause severe losses before the parasites appear in any numbers. Theoretically at least, by releasing laboratory-reared parasites in cane fields in the spring the first generations of moth borer eggs would be parasitized, and the pest would never have a chance to become abundant later in the season.

Puerto Rico has no such distinct winter season, with freezing or near-freezing temperatures, and to conduct release experiments intelligently here, it was necessary first to know when and where the parasites could be used most advantageously. For the past five years, extensive observations have been made on the seasonal abundance and natural parasitism of the eggs of the borer in all parts of Puerto Rico, of which the results in detail will be published in a separate paper. During three years experiments have been conducted on the release of parasites at various localities at different times of year, the results of which are summarized in the accompanying table (Table 1), those least successful being placed first.

Quite unexpected was the discovery that almost a fifth of all borer eggs in

[1] Published with the approval of the Director of the Agricultural Experiment Station of the University of Puerto Rico; published in Spanish as Bulletin No. 61.

Table 1.—Summarized results of all releases of laboratory-reared *Trichogramma minutum* in Puerto Rican cane fields, arranged with the least successful first.

LOCALITY	DATE OF FIRST RELEASE	TOTAL PARASITES RELEASED	FRESH EGG-MASSES	RESULTING PARASITISM			NET RESULT
				Days Later	Release Field	Check Fields	
Santa Elena, Toa Baja	Mch. 3 1939	200,000	none none	26	down 50%	down 3%	−47%
#40 3d Dist. Coloso	Oct. 10 1940	200,000	10 fewer	13	unchanged	up 38%	−38%
Santa Rita 4 Guanica	Apr. 17 1941	200,000	2 more	20	up 20%	up 58%	−38%
Victoria, Coloso	Sept. 29 1937	25,000	1 none	9	unchanged	up 28%	−28%
Santa Rita 11 Guanica	Sept. 9 1937	25,000	5 fewer	8	down 12%	zero	−12%
Abraham Quebradillas	Dec. 15 1937	100,000	6 fewer	26	down 19%	down 13%	− 6%
P. Sustache Isabela	Jan. 11 1938	800,000	3 fewer	65	up 24%	up 25%	− 1%
#27 3rd Dist. Coloso	Oct. 21 1937	50,000	none none	27	unchanged	up 100% down to zero	0
Santa Rita 9 Guanica	Dec. 29 1937	200,000	7 fewer	28	unchanged at zero	unchanged at zero	0
Fraternidad 35, Guanica	Mch. 14 1941	200,000	8 fewer	34	unchanged	unchanged	0
Maria Antonia 16, Guanica	Nov. 17 1938	1,000,000	4 fewer	20	up 50% (complicated by *Prophanurus*)	up 45%	0
Barrancas 233 Guayama	Dec. 12 1940	400,000	3 fewer	21	unchanged at zero	down 6%	6%
Llinas & Cia Yauco	Nov. 2 1937	200,000	8 fewer	9	up 8%	no check	8%
Esperanza 8 Salinas	Mch. 27 1939	600,000	11 fewer	8 61	up 37% up 26%	up 24% up 19%	13% 7%
Vieja 10 Aguirre	Mch. 15 1939	200,000	2 2	12	unchanged	down 12%	12%
Punta Brava Fortuna, Ponce	Jan. 29 1941	1,000,000	12 fewer	43	up 21%	up 5%	16%
Santana (ratoon) Arecibo	Nov. 27 1940	600,000	10 fewer	22	up 39%	up 20%	19%
Santa Rita 1 Guanica	Oct. 6 1937	25,000 25,000	2 more 7 fewer	27 10	up 20% down 20%	down 1% down 4%	21% −16%
Santa Ynez Loiza	Jan. 9 1941	200,000	2 fewer	13 35	zero up 61%	down 22% down 4%	22% 65%
Las Claras Arecibo	Oct. 23 1940	400,000	6 fewer	35	unchanged	down 24%	24%
Cundeamór Hda. Quemao, Ponce	Sept. 13 1938	800,000 desert strain	18 fewer	72	up 42%	up 15%	27%
Martín, Hda. Quemao, Ponce	Sept. 15 1938	800,000 humid strain	34 more	72	up 45%	up 13%	32%
Vieja 10 Aguirre	Jan. 24 1941	600,000	26 fewer	7	up 20%	down 13%	33%
Josefa Guayama	June 20 1938	300,000	7 more	15	up 48%	down 1%	49%
Matilde 3 Ponce	Apr. 20 1939	1,100,000	14 more	24	up 33%	down 17%	50%
San Ysidro 201, Loiza	Sept. 23 1940	600,000	8 more	16	up 67%	up 18%	49%
Verdaguer 32, Guayama	Dec. 30 1940	600,000	12 more	44	up 68%	unchanged	68%
Santana (plant) Arecibo	Dec. 19 1940	400,000	8 fewer	48	up 59%	down 6%	65%
Julia 18 Dorado	Mch. 27 1941	600,000	34 fewer	23	up 57%	down 9%	66%
Flora, Hda. Quemao, Ponce	Oct. 29 1940	1,000,000	12 more	17	up 70%	unchanged	70%
Julbe Peña Humacao	Dec. 14 1938	200,000	8 more	9	up 80%	unchanged	80%
Santa Rita 11 Guanica	Apr. 13 1938	700,000	4 more	8	up 80%	unchanged	80%
A. Rivera Vega Alta	Mch. 19 1941	200,000	22 more	7	up 67%	down 17%	84%
Santa Rita 11 Guanica	Nov. 2 1937	600,000	7 7	66	up 80%	down 9%	89%

Puerto Rico are destroyed by a small black ant, *Monomorium carbonarium ebeninum* Forel. This is a generally inoffensive and ordinarily unnoticed ant whose presence in cane fields is neutral or beneficial. Unfortunately, fresh borer eggs and those previously attacked by parasitic wasps are alike acceptable to these ants, which undiscriminatingly eat them all. However, where the egg parasites are normally least abundant, as at Guanica, this ant is most numerous, and almost equals the parasitic wasps in the number of eggs which it destroys.

Two minute egg-parasites of *Diatraea saccharalis* occur naturally in Puerto Rico. The black Scelionid wasp, *Prophanurus alecto* Crawford, is of little economic importance because of its erratic occurrence. The common dependable parasite is *Trichogramma minutum* Riley, which occurs in all parts of the Island at all times of the year. In any locality where borer eggs are numerous, parasitism by *Trichogramma* often approaches and sometimes reaches 100 per cent effectiveness, and even at localities where host eggs average least abundant, over a quarter of them are parasitized.

In the northwestern part of Puerto Rico, from Coloso to Isabela, Quebradillas Camuy and Arecibo, and in some years half way along the north coast, as far as Manati, Dorado and Toa Baja, the number of egg-masses of *Diatraea* to be found in cane fields increases very rapidly in the spring, reaching a sustained maximum in mid-summer, dropping very sharply in early September, and remaining low during the autumn and winter. The increase in apparent seasonal abundance of borer eggs in the spring is closely paralleled by parasitism by *Trichogramma* which averages 80 per cent during the spring and summer months. This supplemented by destruction of some egg-masses by ants, approaches close to perfect natural control. Indeed, it would appear that the sudden drop in abundance of host eggs in September is due to this natural control for the previous 5 months: a perfection of natural control from which the borer does not begin to recover until the following spring, when spring rains and higher temperatures presumably stimulate oviposition.

In the remaining four-fifths of the coastal cane-growing area of Puerto Rico, the waves of abundance of egg-clusters of the borer are usually of much shorter duration, occurring for no apparent reason at any particular time, and they disappear with equal suddenness without any obvious cause. The factors responsible for the initiation, height and the usually much shorter duration of the waves have not been determined. Temporarily effective natural control, even with often almost as many egg-clusters eaten by ants as attacked by parasites, rarely occurs because of the shortness of the period of the wave. Irrigation so modifies humidity

Table 2.—Number of fields in 100 suitable for the release of egg-parasites, *Trichogramma minutum* Riley, in Puerto Rico, 1936–1941.

LOCALITY	LOW MONTHS			HIGH MONTHS								AVERAGES		
	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mch.	Apr.	May	all	ratoon	plant
South Coast															
Buanica	0	0	0	28	22	**30**	16	19	16	15	11	0	14	10	17
Guayanilla	0	0	0	0	16	0	9	26	15	11	0	20	9	8	11
Ponce	0	0	4	12	16	17	24	**39**	20	16	10	5	14	7	18
Santa Isabel	0	0	0	10	13	**37**	15	14	19	7	9	7	10	4	18
Salinas	0	0	4	8	16	24	25	27	**34**	28	15	13	17	10	**21**
Guayama	4	0	6	8	5	19	24	7	14	7	9	2	9	5	11
East Coast															
Yabucoa	0	7	8	24	8	12	7	14	13	0	11	0	8	6	10
Humacao	0	0	8	10	6	23	25	0	7	14	12	10	10	9	12
Fajardo	0	0	4	8	14	0	13	10	4	8	0	4	5	4	7
North Coast															
Loiza	5	0	0	14	0	4	13	15	14	**4**	4	14	7	8	6
Dorado	12	0	0	11	19	**11**	8	13	11	**19**	10	27	11	**11**	**11**
Manati	9	0	0	0	0	15	5	0	16	15	0	0	7	4	7
Arecibo	14	5	0	0	4	16	9	0	0	4	5	5	5	4	7
Quebradillas	0	0	3	4	9	5	17	8	0	18	0	13	7	2	11
Isabela	0	5	6	8	0	0	11	16	0	19	0	0	7	3	12
Coloso	0	0	0	11	10	0	0	6	11	5	0	0	4	0	7
Averages by Month	2	1	3	10	10	13	**14**	13	12	12	6	7			
Ratoon	4	1	3	8	11	**15**	4	13	8	14	6	4			
Plant	1	2	4	11	10	14	14	**17**	12	10	10	14			

that rainfall, varying from less than 30 inches to nearly 90 inches per year, can not be proved to be a factor, and the variations in temperature are within too narrow limits to produce an effect. Height and variety of cane has no effect on abundance but ratoon cane of which the trash has not been burned averages greater abundance of host eggs and higher parasitism than plant cane or ratoon cane of which the trash was burned.

The waves of abundance of egg-clusters at any particular locality are the average of numerous and varied fields, and often the field with most egg-clusters has many times as many as the field with fewest. Parasitism by *Trichogramma* is quite as variable within a region as is abundance of egg-clusters. In general, high parasitism is found in fields with most egg-clusters, and averages show this by month and by locality without exception. Conditions in individual fields, however, are entirely unpredictable, and in this lies all hope for the successful use of laboratory-reared parasites in Puerto Rican cane fields. Indeed, it is because of this great variation in conditions in individual fields, not following a set seasonal pattern except in the northwestern corner of Puerto Rico where natural control is most effective, that an opportunity for the successful release of *Trichogramma* is presented.

In a region where most fields have many egg-clusters and high parasitism, one or more fields with comparable abundance of egg-clusters may have little or no parasitism. Releases in such fields have invariably been successful, usually resulting in a higher eventual parasitism than the average of the check fields. It might be argued that to bring about such parasitism artificially is somewhat pointless, as eventually it would occur naturally, but the whole point in making releases at all is to obtain immediate results instead of waiting for what may happen eventually.

As a converse to this condition, if all fields in a region have some fresh egg-clusters and no parasitism, release of parasites in the field with the largest number of egg-clusters while sometimes successful, quite as often results in only temporary parasitism in the field of release. This may be due entirely to exceptional abundance of eggs in the sample chosen for examination, not typical of the entire field. Or it is most likely to occur if fewer egg-clusters are found in later weeks, for conditions unfavorable to oviposition by the host appear to be equally unfavorable to attack by the parasite. Such fields, with comparatively few fresh eggs, indicated as "fewer" in the table under the number of fresh eggs at the time of first release, are not suitable for releases, and their selection in the first place was an error. Had inspection of fields at shorter intervals made possible the discovery of the abundance of fresh eggs earlier, before the peak of abundance had been passed, releases made might have been successful. If the number of fresh eggs at least remains constant, or increases after the release of parasites, indicated in the table as "more" under the number of fresh eggs at the time of first release, this is an indication of favorable conditions for attack by parasites, as well as for oviposition by the female moth borer. Parasitism will occur and continue to increase due entirely to the release of the parasites, quite uncontaminated by the possibility of natural parasitism, which remains at or near zero in the checks.

Our experiments have indicated, as indeed common sense would suggest, that release of laboratory-reared parasites is likely to result only in failure when fresh host eggs are scarce, or, if fresh eggs are abundant, can not be proved to be due to the release when natural parasitism is high. From the practical standpoint, fields with few fresh egg-clusters are not worthy any attempt at control when the pest is so scarce, and those with naturally high parasitism certainly do not need additional parasites. Put on a statistical basis, success is hardly to be expected if less than five fresh egg-clusters are to be found in a field during an hour's search, and certainly can not be proven if natural parasitism is over 33 per cent. These are the absolute minimum conditions: with results more decisive if parasitism is very low or non-existent, and proportionately more likely to be successful if the abundance of fresh egg-clusters considerably exceeds the minimum of five.

Of fields meeting these minimum conditions, 445 were noted during the five years' observations in Puerto Rico out of a total of 4707, approximately every tenth or eleventh field. Evenly distributed, finding such conditions might seem difficult, and indeed the real purpose of the latter part of the investigation was to find some

sign or indication of how they might be predicted without continued inspection of all fields. We found no such sign or indication, and their occurrence can not be predicted from anything we know at present, but a preliminary inspection of 10 minutes is sufficient to indicate all that one needs to know in practise. If no fresh egg-cluster is found in the first 10 minutes of inspection, there is little point in looking further. If one fresh egg-cluster is found in the first 10 minutes, conditions at least come up to the irreducible minimum; if two or more egg-clusters are found, the field is worth careful inspection, and in most cases will be found suitable for releases. Actually, their distribution is by no means uniform as to locality or season (Table 2). In 100 fields of plant cane, 12.4 are of this character, but of ratoon fields only 6.4. Only at Dorado and Toa Baja of all the regions examined, was the number of such fields equal in plant and ratoon: 11 in 100. Twice as many fields of plant cane at Ponce, Salinas and Guayama were suitable for the release of parasites as of ratoon cane, and Santa Isabel had four and a half times as many. Even greater were the contrasts in the northwestern corner of the Island, and Coloso had no fields of ratoon cane of this character where the trash had not been burned.

During the month of July, hardly 1 field in 100 meets these conditions, only 2 in 100 in June and hardly 3 in 100 in August. April and May have more of these exceptional fields, but it is only beginning in September and October that they constitute a tenth of all fields: in February and March they average 12 in 100, 13 in November and January, and reach a high of 14 in 100 in December. By localities, only 4 such fields were found in 100 examined at Coloso where the near perfection of natural control makes their occurrence least likely, and 5 at Arecibo and Fajardo, but Ponce and Guanica had 14 in 100 and Salinas 17. Combining locality and month, January at Ponce had 39 such fields out of 100 examined from 1936 to 1941. Santa Isabel 37 in November, Salinas 34 in February and Guanica 30 in November. These figures show what was observed from 1936 to 1941, and give only an indication as to what may be expected in other years, but in general are so consistent as to indicate a strong probability that during any of the autumn, winter or early spring months of any year one should find one out of every four or five fields suitable for the release of parasites at these localities. At most localities on the eastern and northern coasts during the winter the chances are only slightly less of finding fields with sufficient fresh *Diatraea* egg-clusters to justify attempts at control by the release of laboratory-reared parasites. Not only plant cane, but even ratoon cane offers suitable conditions with sufficient frequency not to be entirely neglected.

Experimental releases have an equal chance for success at any locality, regardless of how low are the chances of finding suitable conditions at that locality at that time, if a field can be found which meets the requirements of an abundance of fresh-egg-clusters and low parasitism at the time of release. It certainly is like looking for a needle in a haystack, however, to attempt to find the exceptional field in mid-summer, and in practise, attempts at release should be confined to the autumn, winter and spring. The northeast coast, because of scarcity of egg-clusters at all times of year, and the northwest coast, because of normal near-perfection of natural control, offer the fewest opportunities for conducting successful releases. The south coast during the fall and winter has the greatest number of such exceptional fields, and in practise would seem to offer the best chance for the commercial use of this method of control. In this region also, indiscriminate releases, without preliminary inspection of fields, but at a time when conditions are most generally suitable, might be practical, although inevitably involving a waste of two-thirds to four-fifths of the parasites.

The benefits derived from the releases appear as prompt increase of parasitism of moth borer egg-clusters in the fields of release, which gradually disperses to the surrounding fields to leeward. It can not be proved by a marked difference in stalk injury when the cane is harvested ten or fifteen months later, but only by the general lowering of infestations due to the lower population level of the borer caused by the higher parasitization of its eggs by *Trichogramma*.—2-26-43.

The Occurrence of Parthenogenetic Females in Some Strains of Honeybees

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It has been established beyond all doubt that male honeybees regularly develop from unfertilized eggs, and females (queens and workers) from fertilized eggs, as first set forth by Dzierzon in 1845. This also holds true for most insects of the order Hymenoptera. Females resulting from unfertilized eggs have also been reported in several races of the honeybee, but it has been generally assumed that these were exceptions. Hewitt (1892, reviewed by Anderson 1918), working with Punic, or Tunisian, bees, imported from North Africa to England, reported that when a colony of these bees becomes queenless, as for example by the loss of the virgin queen on her mating flight, laying workers will develop promptly, and queens, workers, and drones will be reared from the eggs produced by them. He states that "the instinct seems perfect in the Punic bees; only partly so in Syrians, and quite absent in our native bees." In the bees native to the Cape region of South Africa similar conditions exist, as first reported by Onions (1912) and later confirmed by Jack (1916). Parthenogenetic females have also been found in the parasitic wasp *Habrobracon juglandis* (Ashm.) by Whiting (1924), and genetic investigation by Speicher (1934) has shown them to be normal diploid individuals.

In the following paragraphs further proof is given that female honeybees can be produced from unfertilized eggs, and evidence is presented to show that this characteristic may be more widespread among the different races of bees than has been commonly thought.

MATERIAL AND GENERAL METHODS EMPLOYED.—Three strains were used, a golden and a three-banded strain of the Italian race and a strain of Caucasian origin. A considerable number of queens of each strain were induced to begin laying as virgins under conditions that excluded any possibility of mating. Queen cells were placed in incubators, and as soon as the queens emerged they were transferred to cabinets maintained at 33° C. and a relative humidity of 25 to 30 per cent. After about 25 days their wings were clipped and they were introduced into nuclei behind queen excluders. A few queens were introduced while in the cells and clipped the first or second day after emergence.

In some experiments greater precautions were taken to make sure of the identity of the females produced. Virgin Italian queens were maintained in nuclei stocked with Caucasian worker bees, and vice versa, so that progeny of queens could be distinguished from progeny of workers.

The occurrence of female progeny was determined in two ways: (1) by examining the brood, which was mostly drone brood, and uncapping those cells that were capped flat and therefore suspected of containing worker pupae, and (2) by transferring young larvae and attempting to rear queens from them by the usual method.

RESULTS.—The majority of the virgin queens that started laying did so between 30 and 40 days after emergence. Fifty of them produced enough brood to constitute a reasonably good test. In the brood of 21 of these queens some worker pupae were found.

The exact percentage of eggs developing into females could not be determined, since many of the drone larvae and pupae developing from unfertilized eggs die and are cleaned out of the comb before they mature. It was estimated, however, that not more than 1 per cent of the eggs of any of the queens tested developed into workers. A more accurate percentage is probably obtained when an attempt is made to rear the young larvae into queens by regular queen-rearing methods, because all larvae are given the optimum conditions for the development of female larvae. Of 710 larvae transferred from the brood of 1 virgin queen of the golden strain, 6, or 0.85 per cent, developed into queens.

The three strains differed considerably in the percentage of virgins producing female offspring and also in the percentage of females produced by individual

[1]In cooperation with Louisiana State University.

queens. Of 13 virgin Caucasian queens three (23 per cent) produced a few workers, and in the two Italian strains one out of 11 three-banded queens (9 per cent) and 17 out of 30 golden queens (57 per cent) produced some workers. In the Caucasian and three-banded Italian strains no more than two worker pupae were found in the brood of any one queen, but in the golden Italian strain from one to five were found. The average brood area examined was about the same in the three strains.

Either the queen or the workers in the nucleus could have laid the eggs that developed into most of the parthenogenetic workers; however, it was proved that the queen laid a few of them. To obtain this proof, advantage was taken of the difference in color of the two races used, the Italians being yellow and the Caucasians black. Italian queens were maintained in nuclei stocked with Caucasian bees and kept in an isolated location a mile away from any other known Italian bees. The nuclei were examined regularly to make sure that no stray Italian bees drifted in. Any yellow bees that emerged in this yard were killed, or removed, before they reached flying age. Caucasian queens were maintained in a similar manner in a yard stocked with Italian worker bees. Under these conditions any emerging worker of the color of the queen contained in the nucleus was certain to be a daughter of this queen. Several of the Caucasian and golden Italian queens were in this way shown to produce worker progeny. One of these worker bees emerged in a screened cage where there was no possibility of its having drifted in.

One queen produced worker progeny under conditions that excluded all possibility of fertilization. She was one of several golden queens that were introduced in queen cells to very small nuclei which had been checked and rechecked to make sure that no drones or queens were present. A queen excluder was kept over the entrance, and the queen was clipped as soon as she emerged. When this queen started laying, she was introduced to an established Caucasian nucleus replacing a Caucasian queen. This nucleus also was examined again and again to see that no drones were present at any time. It was kept in the location where only Caucasian nuclei were kept and where all nuclei were periodically checked to eliminate any yellow workers that might have drifted in or emerged as parthenogenetic females. All queens present in this yard were yellow Italians and were clipped. The brood produced by the queen in question was watched very closely and some yellow worker bees are known to have emerged.

Six parthenogenetic queens were reared from a golden Italian virgin queen maintained in a nucleus stocked with Caucasian bees. Three of these were lost before any use could be made of them. One was artificially inseminated and another permitted to mate naturally, but both were lost before they started laying. The sixth queen was held until she started laying as a virgin, and then a daughter queen was reared from her. The fact that two generations of parthenogenetic queens were obtained indicates that such queens are probably normal diploid individuals.

DISCUSSION.—In the foregoing experiment most possibilities of error were guarded against. There are, however, some questions which might be raised. In the first place, could the few worker progeny have developed from eggs already in the combs of brood when the nuclei were made up? This possibility is very remote, since from 30 to 40 days usually elapsed before virgin queens started laying, and it has not been shown that eggs can survive for this length of time. Furthermore, a parthenogenetic yellow queen was reared from an Italian (yellow) virgin queen that had been for 10 weeks in a nucleus to which only adult Caucasian (black) bees had been added at the time it was made up and during the period of observation.

Again, could the worker-producing eggs have been stolen from other hives? This was possible under the experimental conditions, since some of the queens present in the Caucasian and Italian test yards were mated queens of the other race and fertilized eggs were therefore available. It is not likely, however, that all these females arose from this source. When a colony of South African bees becomes queenless, both laying workers and parthenogenetic females are produced in great numbers. It can hardly be maintained that all of them arise from stolen eggs

The discovery of parthenogenetic females in three domestic strains, representing two races of bees in which it was

thought such females did not occur, brings up the question of how universal is this characteristic among the recognized races? It has been generally believed that such females do not occur in the European races, although no extensive search has ben made for them. Hewitt (1892), who found parthenogenetic females in the Punic bee imported into England, states that they do not occur in the native bee there. Since much experimental work has been done with these races, it seems likely that parthenogenetic females would have been reported if they were at all common. On the other hand, many queens have been reported to appear unexpectedly in hopelessly queenless colonies of these races and, although many explanations have been offered, the most logical one in view of present knowledge, that they arise from eggs deposited by laying workers, has never been stressed.

The data given in this paper give no proof that parthenogenetic females occur in the Caucasian and Italian races in their native lands. The strains tested could easily contain some African blood, since bees have been imported from many parts of Europe, Africa, and Asia, into the United States. Between 1866 and 1880 many attempts were made, some successfully, to introduce Cyprian, Syrian, Egyptian, and Punic bees. All these races were propagated to some extent and queens offered for sale, but none of them proved popular and their propagation was soon discontinued. No doubt these races mixed with the common Italian bees of this country, and the two Italian strains tested in these experiments may have contained some of this blood. It is commonly thought that the golden bee developed in this country is a mixture of the Cyprian or Syrian with the Italian race. The Caucasian strain tested has not been renewed by recent importations, and probably considerable outside blood has crept into it, because it is being maintained in a region where yellow bees are predominant.

There remains little doubt, then, that parthenogenetic females occur more commonly than has been heretofore believed, at least in the domestic strains in the United States, but more observations under the proper experimental conditions are necessary to show how universal this characteristic is among the bee races and varieties of the world.

SUMMARY.—Parthenogenetic females were found to occur in three strains of bees. Of 13 laying virgin queens of a Caucasian strain, 3 produced a few workers; and in two Italian strains 1 out of 11 (three-banded strain) and 17 out of 30 (golden strain) produced some worker offspring. The number produced by any one queen was estimated not to exceed 1 per cent. Both workers and queens produced parthenogenetically appeared to be normal diploid individuals. Two generations of parthenogenetic queens were obtained. Heretofore such females have been reported only among the native bees of Syria, Tunisia, and the Cape region of South Africa. However, the data here presented indicate that this characteristic is more widespread than has been commonly believed and suggest that the many queens that have been reported to appear unexpectedly in hopelessly queenless colonies can best be explained as having arisen from eggs laid by laying workers.—1-16-43.

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SCIENTIFIC NOTES

The Control of the Oriental Fruit Moth by Mechanical Means

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Control of the Oriental fruit moth by the use of insecticides has, in general, been unsuccessful. Various other means of holding the insect in check have at one time or another shown promise and include:

1. Early spring cultivation around the fruit trees, timed to destroy the overwintering insects that have transformed from the larval into the pupal state. Other supplementary measures, such as the application of paradichlorobenzene, the operation of bait traps, and the maintenance of sanitary measures in the orchard and packing shed have been used.

2. The introduction of parasites, not native to this country, or by the special manipulation of native parasites.

3. The regular periodic removal and destruction of infected twigs and fruits throughout the season.

Most outstanding results have been accomplished by well executed sanitary measures. The introduction of parasites from other countries or from other sections of this country for the control of the Oriental fruit moth has been a most important aid to the peach industry. However, there are certain localities in most peach growing areas wherein parasites have not been successfully established. In such sections some other means of control is needed, at least until parasites become more effective.

Harvest infestation records taken annually in commercial peach orchards in southern Indiana show that the Oriental fruit moth is making the growing of peaches extremely hazardous. They show, further, that neither parasites nor spray programs are giving the necessary aid in all localities. In the two counties where work was conducted the average infestation of Elberta at harvest time in 1937 amounted to 30.7 per cent, in 1938 it was 43.7 per cent, and in 1939 the average infestation was 21.0 per cent.

The practice of the removal and destruction of infested twigs and fruit at short intervals, beginning early in the season, to prevent a high harvest infestation is a recommendation commonly made in Europe and Asia but until recently this method has received little attention in the United States. Many have advised against such mechanical control. The reasons given have been varied, but usually the ones most often mentioned are that such practices would involve too much tedious labor, and that the reproductive possibilities of the insect are so great as to preclude any hopes of success.

In an orchard well situated for such a study, records were kept in 1935 of the effects of the periodic removal of infested twigs and fruits. This orchard was a 95-acre development and twig clipping was carried on as a regular orchard practice. The year before, approximately 25 per cent of the peaches were infested. After clipping, the average total infestation was 6.1 per cent. In 1938, it was 1.5 per cent visible entries. In 1939 clipping was carried on until the middle of June, when the number of infested twigs became small enough that the grower decided it would not pay to go over the orchard any more that season. At harvest time (August 25) the infestation had built up until it averaged 13 per cent of the crop.

In 1940 there was no crop and in 1941 a different orchard was used for the clipping studies. The planting at the Purdue Experimental Orchard was grown and pruned to facilitate the clipping operation. At harvest time the wormy peaches averaged only one in 130. An orchard less than a mile away had an infestation of 12 per cent Oriental fruit moth and, in addition, 2 per cent curculio.

Cost figures of twig clipping programs have been computed for all of the studies made, the most recent being with Gage Elberta, which ripen from August 25 to September 3. In 1941 the clipping cost 3 cents a bushel, the crop was only 0.5 per cent wormy and sold at $2.00 a bushel. This left a net of $1.97 a bushel. The infestation in the area of the studies (Lawrence and Orange counties, Indiana) for 1941 was 21 per cent on midseason varieties. Since wormy peaches brought only 50 cents a bushel, the 21 bushels sorted out of 100 bushels sold for only $10.50. If the remaining 79 bushels were sold at $2.00, the entire 100 bushels would sell at an average of $1.68 per bushel. This is 31 cents a bushel less than for the peaches from the clipping area.

So far the discussion has been limited to midseason varieties of peaches. One year (1938) of twig clipping studies was conducted, using William's Favorite which ripen about September 20. The block of 400 trees used was surrounded by both early and midseason varieties and at harvest the infestation was 98 per cent. With this failure to hold the insect in check, it was concluded that control could not be obtained on such late varieties by this method, or, if control was to be accomplished, the block of late peaches under treatment would need to be an isolated one to eliminate the immigration of moths from other areas.

Accordingly, the next attempt at mechanical control by clipping of infested twigs was carried out on a block of mature Fleener peaches. Some of the trees were 18 feet high. This variety ripens in October and the block of 145 trees was about a half-mile from any other peaches, although on the same farm as the William's Favorite block already mentioned. The infested twigs and peaches were removed 20 times during the season and stepladders had to be used in doing the work. At harvest the infestation amounted to 30.2 per cent of the picked fruit—that is, excluding the wormy peaches in the 11.5 per cent of the fruit removed during the growing season because it was wormy or otherwise faulty. When the wormy ones removed during the growing season are included, the infestation amounts to 38.2 per cent. The labor cost was $270 for the 145 trees. Five hundred and eight bushels were harvested, and the selling price was $2.00 a bushel. The grower sold the crop orchard run. His crop brought $1016.

We need not compare the cost of this program with any other when discussing control on this variety, nor is a check needed with which to compare the infestation, because had it not been for the clipping there would have neen no crop to sell. This was amply borne out by two rows of the same variety in another part of the orchard. Here a full crop of fruit was set, no clipping was done, three oil-dust

[1] Journal Paper Number 92, Purdue University Agricultural Experiment Station.

applications were made, and at harvest time worms had taken all but about 50 peaches per tree.

This measure of success with one of the latest peach varieties was most encouraging. The growing of peaches ripening later than midseason Elberta has been dissuaded for many years and at present there are but few plantings of late varieties left in the central states.

The clipping program precludes the necessity of carrying out many orchard operations which have been common. The Indiana peach schedule for 1943 suggests the application of six sprays or dusts. If the clipping program is adopted, three of these applications may be dropped entirely and the lead arsenate for curculio control left out of another. No special thinning operation is necessary. Unless there is a poorly kept neighboring orchard, losses from brown rot, curculio, and the Oriental fruit moth will decrease for several years after the clipping program is adopted.—4-8-43.

The Susceptibility of Parasitic Hymenoptera to Sulfur

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In Connecticut, Schread & Garman (1934) made extended observations on the effect of sulfur on the parasitization of the oriental fruit moth by the egg parasite *Trichogramma*. It was noted that the sulfur was lethal to *Trichogramma* only at temperatures *above* 70° F. The killing effect was in proportion to the increase in temperature. This may be explained by the fact that when sulfur is in contact with living protoplasm and a reduction to hydrogen sulphide occurs, the amount of gas evolved varies with the temperature, being low at 70° F. or below and reaching a peak at about 95° F. (Shepard 1942).

Schread & Garman state that when the average temperature is 80° F. or above during egg deposition by the peach moth, there will be less parasitization by *Trichogramma* in peach orchards where sulfur is used than in untreated orchards. In Connecticut, sulfur affected the amount of parasitization in the field only if applied at the time of parasite liberations. This is probably because of frequent rainfall.

In 1942, at the University of California Citrus Experiment Station, Riverside, observations were made on the effect of sulfur on the black scale parasite *Metaphycus helvolus*. At weekly intervals for three months, leaves from a citrus orchard that had received a commercial dusting with sulfur on May 6 were brought into the laboratory in which the temperature was 80° F. Each time several adult *M. helvolus* were released on leaves that were laid flat. They were allowed to move over the leaf surfaces a few times and were then recollected.

The first observable reaction was that of rapid cleaning movements of the tarsi and then the antennae. This was followed by a paralysis of the antennae so that they dragged beneath the body. Death ensued within 24 hours, either because of a toxic effect of the sulfur or of inability to recognize food.

The toxicity of the sulfur in the test orchard gradually decreased until, at the end of three months, August 10, it was no longer lethal to the adult parasites. However, when these parasites, after being confined on the leaves for several hours, were placed with a number of black scales suitable for parasitization, it was found that they were unnize them as hosts in which to oviposit. The ability to do so was lost permanently.

As in the case of *Trichogramma*, the susceptibility of *Metaphycus helvolus* to sulfur increased markedly with temperatures above 80° F. At temperature below 75° F., no injurious effects were noted.

A liberation of hundreds of *Metaphycus helvolus* on a sulfur-dusted tree near Redlands, California, (dusted a week prior to liberation) resulted in 100 per cent mortality.

It is evident that in regions where *Metaphycus helvolus* is present only as adults, during several months of the warm season of the year, the occurrence of large areas of sulfured vegetation may trap and destroy a number sufficient to prevent them from checking the increase of their host. *M. helvolus* is particularly susceptible since it moves rapidly over wide areas.

The variability in the toxicity of sulfur dust to bees, as reported by Brittain (1933), may be an effect of variable temperatures.—3-20-43.

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The Comparative Suitability of Potato and Tobacco as Hosts of the Potato Tuber Worm

LOYD W. BRANNON, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*[1]

In connection with a survey of the potato tuber worm, *Gnorimoschema operculella* (Zell.), conducted by workers and cooperators of the Bureau of Entomology and Plant Quarantine in the various States, the early records sent in showed that the insect is found commonly in tobacco in several of the tobacco-growing States. This led to a renewed interest in the question as to the comparative suitability of potato and tobacco as hosts of this pest. A test was conducted at the Norfolk, Va., laboratory to obtain additional information on the role of the host in moth production.

During the period September 22 to October 12, 1942, inclusive, 66 moths of the potato tuber worm reared from potatoes, and a like number reared from tobacco, received from Norman Allen of Florence, S. C., were placed in separate cages in the laboratory as they emerged from their respective hosts. Each cage contained approximately one-half bushel of new potatoes from the fall crop, purchased in the Norfolk market. Since previous work (Poos & Peters 1927) indicated that the average proportion of sexes is approximately equal, the moths were placed in the cages as they emerged, without regard to sex.

The first stages of the insect reared from moths placed in the two cages were observed in cage 1

[1] In cooperation with the Virginia Truck Experiment Station.

(moths originating from potatoes) on October 29, and in cage 2 (moths originating from tobacco) on November 3. Beginning with these dates, daily removals were made of all stages of the insect found in the two cages. Final examinations of the potato tubers were made on November 25, approximately 6 weeks after the last moths were placed in the cages. The results were as follows:

Cage No.	Origin of Moths	Numbers of Insects Reared from Potatoes			
		Larvae	Pupae	Adults	Total
1	Potatoes	417	39	679	1,135
2	Tobacco	24	13	290	327

The results of this test indicate that tuber worm moths reared from potatoes and placed on potatoes as host food reproduce more readily than do moths reared on tobacco and transferred to potatoes. The population ratio in this test was approximately 3½ to 1 in favor of moths originating on potatoes.—5-5-43.

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Differential Damage to Sweetclover Varieties by the Variegated Cutworm[1]

H. H. Walkden, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

In June 1937 an outbreak of the variegated cutworm occurred in the sweetclover varietal test plots on the Agronomy Farm at Kansas State College, Manhattan, Kan. These sweetclover varieties were then in their second year of growth and were coming into maturity at the time of the attack. They were planted in rows about 20 feet long and 3 feet apart. As the outbreak progressed, it was noted that the different varieties were being damaged in varying degrees, and by the end of the larval feeding period outstanding differences in the extent of defoliation were noted. Estimates of the percentages of defoliation of the different varieties were made on July 10, 1937, after the larvae had reached maturity and ceased feeding.[2] The estimates were made by two persons working independently, and comparison of the results revealed that the difference in estimated damage for a given variety did not exceed 15 per cent in any case. The two estimates were then averaged.

The results are given in the table, the varieties being listed in ascending order of injury. It may be noted that in general the white-bloom varieties sustained less defoliation than did those with yellow blooms, and that degree of injury appears to be correlated with time of blooming, the earlier maturing varieties being more severely damaged. Redfield yellow was the least injured among the yellow-bloom varieties, whereas Germany, a white-bloom variety, ranks with the yellows in point of damage. Madrid yellow 27474, the variety most severely damaged by the cutworms, was considered the most promising variety in the series from the standpoint of agronomic characters. It was noted that the ends of the rows and the border rows (Nos. 1 and 28) showed less injury. Some plants in badly injured rows escaped serious injury. In some rows this condition appeared to be due to a mixture (difference in bloom color), but in other cases plants escaping injury showed no difference in color of bloom. New plantings had been made in an adjoining plot. These plants were small, and no cutworm damage was noted in any of them.—5-5-43.

Sweetclover defoliation by variegated cutworm, Manhattan, Kan., 1937.

Row No.	Variety	Bloom Color	First Bloom Date	Defoliation, Per Cent[1]
28	Evergreen (Ohio)	white	—	25.0
27	Ohio 32–1	white	—	30.0
25	Maccor 14355	white	June 12	32.5
1	Common white 19012	white	June 9	32.5
6	Iowa 704 16585	white	June 17	35.0
19	Chantlands 05647	white	June 12	37.5
2	Common white 19012	white	June 9	40.0
3	Common white (Smerchek) 2461	white	June 10	45.0
24	Common white 20154	white	June 21	50.0
11	Downs 05564	white	June 12	52.5
17	Madrid white 27465	white	June 8	52.5
16	Redfield yellow 40937	yellow	June 26	57.5
13	Madrid white 52916	white	June 9	65.0
22	Arctic 05344	white	June 7	70.0
26	Stone's early 12067	white	June 3	72.5
9	Nungessers 28366	white	June 5	72.5
15	Grundy County 2724	white	May 31	75.0
4	Crystal Dwarf 05326	yellow	June 4	77.5
23	Germany 27291	white	May 24	82.5
12	Madrid yellow 27246	yellow	May 27	82.5
14	Madrid yellow 27477	yellow	May 27	85.0
21	Madrid yellow 27475	yellow	May 26	85.0
20	Common yellow 15830	yellow	May 21	86.5
5	Albotrea 04466	yellow	May 17	87.0
18	Sask. 6517	yellow	May 21	87.5
7	Madison County 04407	yellow	May 17	89.5
8	Common yellow 20023	yellow	May 17	89.5
10	Madrid yellow 27474	yellow	May 26	90.0

[1] Mean of two estimates.

[1] *Peridroma margaritosa* (Haw.), order Lepidoptera, Family Noctuidae.

[2] Credit is due R. H. Painter, of the Kansas Agricultural Experiment Station, for assistance in estimating the damage.

An Unusual Type of Ethylene Dichloride Injury to Peach

John S. Bailey and Arthur I. Bourne, *Massachusetts Agricultural Experiment Station, Amherst*

A peculiar type of injury was observed in a 3-year-old peach orchard following treatment with ethylene dichloride emulsion. The trees were treated on October 1 and 2, 1941, with a 15 per cent emulsion, 0.5 pint per tree. On October 4, 5, and 6 the temperature reached 82°, 88°, and 77° F. respectively. The first signs of injury appeared on October 7.

This injury occurred on very vigorous immature sprouts about 4 feet long that had developed from the crown of several trees cut to the ground following winter injury. Although these sprouts grew from the old trunks well below the soil surface there was no injury either at or below the ground line. A little

FIG. 1.—Injury by ethylene dichloride.

above ground the cambium and sapwood were light brown and slightly watery in appearance. This type of injury increased up the stem but was not severe.

The first observed and most striking type of injury was a bending of the tips of the shoots which sometimes resulted in a double curve like a flattened letter "S." Next the tissue at the top of the curve turned gray and died. Then the tissue died clear through the stem, followed finally by the total collapse of the tip. (Fig. 1.)

The following points are worth noting:

1. The dosage, adjusted for 3-year-old trees, was excessive for tissue less than 1 year old.

2. Unseasonably high temperatures occurred a few days after treatment.

3. There was considerable odor of ethylene dichloride in the soil.

4. The tissues affected were very succulent, immature, and above ground.

Undoubtedly the injury resulted from the rapid volatilization of the ethylene dichloride, but it is surprising that there was no injury below soil level, where the concentration of gas was probably high.—4-5-43.

The Host Preference of the Sweetpotato Weevil

K. L. COCKERHAM, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*[1]

It has been known for many years that the sweetpotato weevil, *Cylas formicarius* subspecies *elegantulus* Summers, breeds in a number of wild host plants, and in recent years more information has been acquired on this subject. Studies of host-plant preferences were conducted during 1940 at Sunset, La., in experimental plots at the laboratory grounds, on sweetpotato farms, and in other environments such as marshes and seashores, to obtain further data upon the role of wild hosts in building up populations of weevils on farms, and to determine more specifically the preference weevils show for the various hosts.

[1] This work was performed in cooperation with the Louisana Agricultural Experiment Station, the Louisiana State Department of Agriculture and Immigration, and the Division of Control Investigations of the Bureau of Entomology and Plant Quarantine.

The following list shows the plants in which the weevil was found breeding naturally during the season:[2]

Plants	Remarks
Ipomoea batatas	Sweetpotato
I. bona-nox L.×*hederacea* Jacq.	"Scarlet O'Hara", annual ornamental; heavy infestation in experimental plots.
I. dissecta (Jacq.) Pursh	Perennial; heavy infestation on vacant city lot.
I. hederacea Jacq.	Heavy infestation in experimental plots; a favorite host.
I. hederacea var. *integriuscula* Gray	Heavy infestation in experimental plots; a favorite host.
I. heptaphylla (Rottb. & Willd.) Voight	Heavy infestation in experimental plots.
I. macrorhiza Michx.	Young plants heavily infested in roots in experimental plots.
I. lacunosa L.	Heavy infestation in experimental plots.
I. littoralis (L.) Boiss.	Heavy infestation on seashore.
I. muricata Jacq.	Light infestation in experimental plots.
I. pandurata (L.) G. F. W. Mey	Infested in experimental plots and on farms.
I. quamoclit L.	Heavy infestation in experimental plots.
I. sagittata Cav.	Several plants tunnelled and one pupa found in marsh.
I. setosa Ker.	Ornamental, very rank growth; heavy infestation in experimental plots.
I. trichocarpa Ell.	Heavy infestation in experimental plots.
Ipomoea sp.	Probably undescribed species. Natural habitat Rio Grande Valley. Light infestation in experimental plots.

In field-plot tests, in which sweetpotatoes and five of the most common wild host species of the genus *Ipomoea* occurring in the vicinity of Sunset, La., were compared, greater numbers of weevils developed in the vines and crowns of the sweetpotato plants than in those of the five wild hosts, as shown in the following tabulation made at the close of the 1940 season:

Host Plant	Average weevils per plant
Ipomoea batatas	35.2[3]
I. hederacea var. *integriuscula*	12.1
I. hederacea	9.2
I. quamoclit	8.3
I. trichocarpa	6.4
I. pandurata	2.3

The experimental plants were grown in plots containing four plants each, there being six plots of each host arranged in a Latin square. The plants were transplanted in June to plots located in an area heavily infested with weevils. Examination of all plants to determine the infestation by the sweetpotato weevil was made in October.

Based upon the number of infested plants, *Ipomoea pandurata* was less attractive than all other varieties, and there were no significant differences in attractiveness between the others. Based upon the number of weevil specimens present, the increased infestation in sweetpotato plants was highly significant over all other plants, and there were more weevils in the sweetpotatoes than in the sweetpotato plants. *I. pandurata* was less attractive than *I. hederacea* or *I. hederacea* var. *integriuscula*, but there were no significant differences in infestation

[2] Identification of these plants was made through the cooperation of the Division of Plant Exploration and Introduction, Bureau of Plant Industry, United States Department of Agriculture.

[3] An average of 57 additional specimens of the weevil per plant were taken from the roots of these sweetpotatoes.

between the other species. *I. pandurata* seemed to have been stunted in the transplanting and did not produce so large and vigorous vines as are generally found growing naturally in fields. This may have had some influence upon the number of specimens in the plants.

In field-cage feeding tests, using large and small plants of both sweetpotato and *Ipomoea hederacea* var. *integriuscula*, adults showed a decided preference for the larger plants. When small plants of sweetpotato and *I. hederacea* var. *integriuscula* were caged together more feeding occurred upon the latter. Under normal conditions sweetpotato plants will grow larger than any of the wild host plants, but this condition may not be true where wild hosts are favored by cultivation or growing in unusually fertile locations.

SUMMARY.—Fifteen species or varieties of wild hosts were found infested by the sweetpotato weevil during these studies. In field-plot tests sweetpotato plants contained an average of 35.2 weevils per plant, while *Ipomoea hederacea* var. *integriuscula*, with 12.1 weevils per plant, had the next highest average number. In field-cage tests containing both large and small plants, adults showed a preference for the larger plants. There was some indication that the size of the plant was the determining factor in the number of specimens breeding in it. These studies emphasize the economic importance of wild hosts, since it is evident that weevils can breed abundantly in them on farms where the cultivated host is suppressed as a control or eradicative measure.—3-9-43.

A Portable Spray Boom for Experimental Plots[1]

GEORGE M. LIST, *Colorado Agricultural Experiment Station, Fort Collins*

Many criticize the use of a randomized plot system in experimental control of row crop pests because of difficulties in approximating field spraying without excessive driving through a field. The portable spray boom herein described can be used to meet this criticism.

The boom is planned to spray a single row with a nozzle arrangement identical with that of the field sprayer booms but is carried by hand, the pressure being supplied from the machine at the end of the plot through a high-pressure hose. The boom and carrying device are constructed of standard spray-machine accessories and plumbing parts. The center or top nozzle and the supports for the side nozzles are hung on a 4-foot strap iron of the width to fit the standard clamps put out by the manufacturer. The liquid is carried from a single intake to the side nozzles by high-pressure hose so the distance between nozzles can be adjusted to different sized plants. The side nozzles are dropped by using the standard galvanized piping. Interchangeable lengths of 16, 20, and 24 inches permit adjusting to the height of various row crops. Double elbows should be used for the side nozzles, thus permitting their angular adjustment for the best coverage. The boom is suspended on a 10-foot, three-quarter inch galvanized pipe for carrying. Hand holds on the ends are made by using a standard plumbing T with 4-inch pieces of pipe for the handles. A strap-iron, square-

[1] Paper No. 164, Scientific Journal Series, Colorado Agricultural Experiment Station.

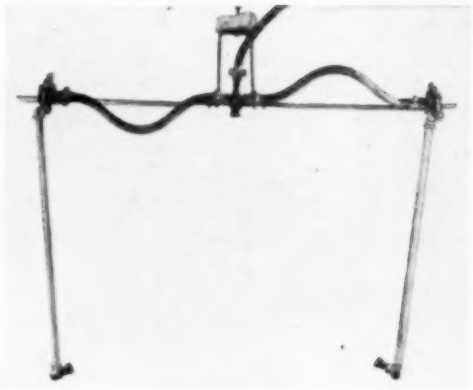


FIG. 1.—The portable spray boom showing the nozzle arrangement and adjustment features.

angled U about 6 inches in height will be needed to attach the boom to the handle and still have the hose attachment accessible. If the strap iron is bolted to the handle with a small block of wood between them, the boom will stay at the desired angle to the handle to permit one man on each side of the row to carry it directly over the plants.

A convenient arrangement of plots is to have them in paired blocks with a 12-foot space between the pairs for driving through with the spray machine.

FIG. 2.—Portable spray boom in use on experimental plots of potatoes.

A 4-foot aisle between the blocks of a pair prevents overlapping of treatments. The plots are then sprayed from the end. A 50-foot hose is needed for plots 35 feet long. A 75-foot hose works well for plots 50 feet long. It is desirable to have an even number of rows in a plot. By use of a pressure water meter the rate of spray delivery with known pressures and nozzle disc aperatures can be determined. The rate of application is then determined by the time. Three men handle the equipment, two to carry the boom and the third to assist with the hose and to keep time by means of a stop watch.

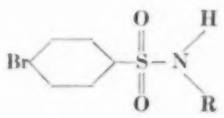
The writer has used the boom very satisfactorily for two seasons in spraying experimental plots of beans and potatoes. The desired rate of application can be more accurately obtained than with a horse-drawn or even a tractor-drawn sprayer.—5-14-43.

Tests of N-Substituted P-Bromobenzenesulfonamides Against Codling Moth

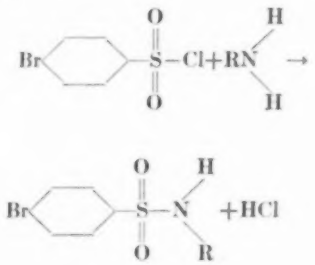
E. H. SIEGLER and S. I. GERTLER, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

In the course of laboratory investigations of organic compounds for their possible value as insecticides, a number of N-substituted p-bromobenzenesulfonamides were tried against newly hatched larvae of the codling moth, *Carpocapsa pomonella* (*L.*). The results of previous tests of some other sulfonamides have been reported (Siegler & Haller 1942).

The compounds herein included have the general formula:



where R may be an alkyl, an aryl, or a substituted aryl group. In one compound the N is part of a heterocyclic nucleus. The compounds were prepared by the conventional method of reacting p-bromobenzenesulfony-chloride with an amine according to the equation:



The toxicity tests were carried out by the apple-plug method. The compounds were tested at a concentration of 4 pounds per 100 gallons of a 20 per cent solution of 95 per cent ethanol. They were first dissolved in the ethanol and then precipitated in water. The results are shown in table 1, together with data for lead arsenate at the same concentration and check (unsprayed) tests for comparison.

Table 1.—Toxicity of N-substituted p-bromobenzenesulfonamides to codling moth larvae.

Spray Material	Percentage of Apple Plugs	
	Wormy	Stung
p-Bromo-N-ethylbenzenesulfonamide	40	4
p-Bromo-N-o-tolylbenzenesulfonamide	72	12
p-Bromo-N-(p-chlorophenyl) benzenesulfonamide	74	4
p-Bromo-N-butylbenzenesulfonamide	81	0
p-Bromo-N-propylbenzenesulfonamide	83	2
p-Bromo-N-benzylbenzenesulfonamide	87	1
N-(p-Bromobenzenesulfonyl) piperidine	87	3
p-Bromo-N-(o-chlorophenyl) benzenesulfonamide	92	1
p-Bromo-N-(m-chlorophenyl) benzenesulfonamide	92	3
p-Bromo-N-p-tolylbenzenesulfonamide	94	3
p-Bromo-N-amylbenzenesulfonamide	99	0
p-Bromo-N-p-amylbenzenesulfonamide	99	0
Lead arsenate	25	16
Check (unsprayed)	96	0

The most toxic of the sulfonamides was p-bromo-N-ethylbenzenesulfonamide, but it was definitely less toxic than lead arsenate. The other sulfonamides showed little to no toxicity to codling moth larvae.—5-14-43.

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Present Status and Future Trends of Nicotine as an Insecticide

N. E. MCINDOO, *U.S.D.A., Agr. Res. Adm., Bureau Bureau of Entomology and Plant Quarantine*

There is increasing scarcity of many of the important insecticides and fungicides and a threatened shortage of some, especially arsenicals. Rotenone and pyrethrum, which are wholly imported, have been restricted in their uses by orders of the War Production Board, to conserve the supply. Of all the chemicals used to combat the numerous pests of agriculture, nicotine is unique in that it is a constituent of an American crop plant—tobacco. It has been suggested, therefore, that the production of nicotine be increased so that a sufficient quantity will be available to supplant the uses of scarce insecticides, such as pyrethrum and rotenone, and, to a lesser degree, lead arsenate, in those cases where nicotine offers a satisfactory degree of control. As a step in this direction, the Department of Agriculture on August 15, 1942, approved the diversion of 8,500,000 pounds of low-grade tobacco for use in the manufacture of nicotine sulfate and other nicotine insecticides. On the basis of a 3-per cent content of extractable nicotine, this quantity of tobacco will yield 637,500 pounds of nicotine sulfate solution of 40 per cent nicotine content. The present docket pertaining to the 1943 tobacco-diversion program calls for 25,000,000 pounds and that the total payments to be made by the Department therewith be limited to 1,750,000 dollars. The 25,000,000 pounds of tobacco should contribute, on the basis of a 3 per cent content, approximately 1,875,000 pounds of 40 per cent nicotine sulfate.

To what extent can nicotine take the place of the arsenicals, rotenone, and pyrethrum? This question can be answered by considering the known satisfactory and unsatisfactory uses for nicotine sulfate and the other nicotine insecticides.

The Bureau of Entomology and Plant Quarantine in 1936 published a bibliography, including 2,497 abstracts, on the insecticidal uses of nicotine, by McIndoo, Roark and Busbey. The period covered was from 1690 to 1934. According to this literature, nicotine is effective and has been recommended against only those insects having soft bodies and others of minute size, such as mites, thrips, aphids, psyllids, leaf-hoppers, crawling scale insects, mirids, tingids, lice on poultry, midges, mushroom flies, and sawflies. Against such pests nicotine acts usually as a contact insecticide but in certain instances as a fumigant.

According to the literature since 1934, nicotine used as a stomach poison is effective against several insects of larger size, such as the codling moth,

grapeberry moth, casebearers, and others, all of which are Lepidoptera. Nicotine so far has proved ineffective against the Coleoptera, excepting the cucumber beetles and a few others of small size. The present normal uses of nicotine as an insecticide in the United States are shown in table 1. Satisfactory statistics on the quantities of nicotine uses for various purposes have been difficult to obtain, but the best figures are given in this table.

Table 1.—Uses of nicotine insecticides (Calculated in terms of nicotine sulfate solution of 40 per cent nicotine content). Domestic consumption in 1941, 2,406,000 pounds.

USE OF NICOTINE, ACCORDING TO CROP AND INSECT	POUNDS
Fruits	
Apples, several species of aphids and other sucking insects	200,000
Codling moth (used with lead arsenate and oil)	70,000
Codling moth in Mississippi Valley	120,000
Codling moth in Northeast	70,000
Cherries, aphids	10,000
thrips	25,000
Citrus Fruits, aphids	70,000
Currants and gooseberries, several species of aphids	10,000
Grapes, leafhoppers	150,000
grapeberry moth	25,000
Peaches, several species of aphids	40,000
peach twig borer	12,000
Pears, pear thrips	40,000
pear psylla	25,000
Pecans, black pecan aphid	10,000
pecan nut casebearer	5,000
phylloxera	5,000
Plums and prunes, pear thrips	50,000
several species of aphids	15,000
Walnuts, walnut aphid	40,000
Vegetables	
Broccoli, cabbage aphid	25,000
Cabbage and cauliflower, cabbage aphid	87,000
Cantaloupes, melon aphid	10,000
cucumber beetles	10,000
squash borer	5,000
Celery, thrips	35,000
Cucumbers, melon aphid	5,000
cucumber beetles	7,000
squash borer	3,000
Eggplants, aphids	5,000
Mushrooms, mushroom flies and mites	5,000
Onion, onion thrips	5,000
Peas, pea aphid	100,000
Peppers, green peach aphid	7,000
Potatoes, potato, buckthorn, and green peach aphids	30,000
Spinach, green peach aphid	5,000
Strawberries, aphids	5,000
Sweetcorn, European corn borer	25,000
Tomatoes, potato aphid	5,000
Turnips, turnip aphid	11,000
Vegetables in home gardens, certain species of aphids, thrips, mealybugs and whiteflies	300,000
Vegetables in greenhouses, same insects as above	100,000
Watermelons, melon aphid	20,000
cucumber beetles	10,000
Poultry, mites, lice, and internal parasites	100,000
Other crops	
Cotton, cotton aphid	32,000
Flowers in greenhouses and commercial plantings, certain species of aphids, thrips, whiteflies, and mealybugs	150,000
Flowers in home gardens, same insects as above	150,000
Hops, hop aphid	37,000
Shade trees, ornamentals, and nurseries, aphids and other sucking insects	100,000
Premises of man, fleas and ticks	25,000
Total for all uses	2,406,000

INSECTS AGAINST WHICH NICOTINE IS NOT EFFECTIVE.—*Fruit insects.*—Nicotine has been tried repeatedly against the following fruit pests but found ineffective: Plum curculio, apple maggot, grape rootworm, rose chafer on grape, and leaf-chewing caterpillars and May beetles on pecan and most fruits. Arsenicals are effective against them.

Nicotine is ineffective whereas rotenone is effective against the following fruit pests: two species of cherry fruitflies, imported currant worm, raspberry fruitworm, blueberry and huckleberry insects, and the Japanese beetle.

Vegetable insects.—Nicotine is ineffective whereas the arsenicals are effective against the cabbage webworm, tomato fruitworm, southern armyworm, cutworms (various species), pepper weevil, vegetable weevil, strawberry weevil, sweetpotato weevil, tobacco and tomato hornworms, tobacco budworm, Colorado potato bettle, and beet webworm.

Nicotine is ineffective whereas rotenone is effective against the following insects on vegetables: Imported cabbage worm, cabbage looper, diamondback moth, Mexican bean beetle, bean leaf beetle, melonworm, pickleworm, pea weevil, spinach flea beetle, black swallowtail butterfly, and Florida fern caterpillar.

Cotton insects.—Nicotine is ineffective against the boll weevil, bollworm, and cotton leafworm, which must be controlled by the application of arsenicals.

NEW USES FOR NICOTINE.—An expansion of the use of nicotine as a stomach poison against leaf-chewing insects, particularly lepidopterous larvae, may be brought about by further investigations with "fixed nicotines," such as nicotine bentonite, nicotine peat, nicotine zinc thiocyanate, etc. The present nicotine bentonite has certain disadvantages. When it is mixed with alkaline fungicides, especially bordeaux mixture, free nicotine is released; and in this form it is volatile and also very soluble in water and hence is washed off readily by rain. Its effectiveness as a stomach poison is consequently greatly reduced. It is more expensive than lead arsenate and it leaves a heavy, unsightly residue on the fruit. A more serious drawback to the use of nicotine bentonite is its ineffectiveness in the Pacific Northwest. Dean et al. (1942) (Jour. Econ. Ent., vol. 35, no. 3, pp. 387–392, 1942) found it to be unsatisfactory as a substitute for lead arsenate for codling moth control in the Yakima, Wash., district. Because of such limitation on its use as a stomach poison, nicotine bentonite at present replaces lead arsenate to a limited degree only.

It is unlikely that many uses of nicotine as a contact insecticide can be found because nearly all the

numerous known nicotine compounds have already been tried against a wide variety of insects.

Investigations in which nicotine is used as a fumigant should be continued. It may be possible to apply nicotine vapor to trees covered with tents in the manner that hydrocyanic acid gas is applied to citrus trees in California.

FUTURE SUPPLY OF NICOTINE.—It has never been proved economical to grow tobacco merely for its nicotine content, although certain strains of *Nicotiana rustica* have been reported to contain as much as 10 or 12 per cent of nicotine. Consequently, probably 90 per cent of all the nicotine produced has been recovered from stems, sweepings, and trash from tobacco factories and the remainder from low-grade leaf production. The annual production of this by-product nicotine in the United States has never exceeded $2\frac{3}{4}$ million pounds (calculated as nicotine sulfate solution of 40 per cent nicotine content). If more nicotine is to be produced it can come chiefly from low-grade leaf tobacco, which is estimated to contain an average of 3 per cent of extractable nicotine. The present price of nicotine sulfate solution, namely, 80 cents per pound in 50-pound drums, was set by the Office of Price Administration. If leaf tobacco is to be used for the production of nicotine sulfate which cannot be sold for more than 80 cents per pound, the difference between the figure of about $3\frac{1}{2}$ cents per pound for leaves, which the manufacturer can afford to pay, and the actual cost of the tobacco would have to be borne by the Government. If all the tobacco grown in the United States in one year (1452 million pounds in 1940) were extracted, the nicotine obtained would be sufficient to make 100 million pounds of 40 per cent nicotine sulfate solution. The total production of dark tobacco in 1942 will probably be sufficient to permit the use of as much as 20 to 25 million pounds of leaf for the extraction of nicotine.

CONCLUSION.—Nearly 2,500,000 pounds of nicotine (in terms of nicotine sulfate solution containing 40 per cent of nicotine) are used annually in the United States against about 40 kinds of insects of economic importance. Most of these are small and soft bodied, although several species of lepidopterous larvae are included. An expansion of the use of nicotine may be effected by further investigations of nicotine compounds of low solubility in water and of methods of applying nicotine as a fumigant. The possibilities of nicotine as a contact poison have been pretty well explored.

Many important insect pests are not susceptible to nicotine, but are controlled by pyrethrum, rotenone, or the arsenicals. No matter how much nicotine is produced or how low its price may become it cannot serve as a substitute for these materials in the control of many important insects. Nicotine sulfate if available in adequate quantities can, however, serve as a satisfactory substitute for insecticides which are not now available in sufficient quantities for control of the insects set forth in table 1.—2-19-43.

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The Toxicity of Some Heterocyclic Compounds to Young Screwworms

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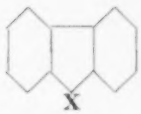
Three dibenzo derivatives of five-membered heterocyclic compounds have been tested against larvae of the screwworm. *Cochliomyia americana* C. & P. They may be represented by the structural formula:



where X may be oxygen (dibenzofuran), sulfur (dibenzothiophene), or the imino (NH) group (dibenzopyrrole). The wide difference in toxicity between these three compounds suggested the preparation and testing of six-membered heterocyclic compounds containing all possible combinations of the above-mentioned substituents in the ring, each in the para position to the other.

The testing procedure used in this work has been described (Melvin & Bushland 1936, Bushland 1940).

The results are listed in Table 1.

Table 1.—Relative toxicity of three 5-membered heterocyclic dibenzo compounds and their 6-membered derivatives in which sulfur, the imino group, or oxygen was added in the ring.

COMPOUND	FORMULA	MINIMUM LETHAL CONCENTRATION[1]
		Per cent
Dibenzofuran and derivatives:		
Dibenzofuran	C_6H_4–C_6H_4 |—O—|	0.05–0.08
Phenoxathiin	C_6H_4–S–C_6H_4 |— O —|	0.03–0.05
Phenoxazine	C_6H_4–NH–C_6H_4 |——O——|	0.17–0.33
Dibenzodioxin	C_6H_4–O–C_6H_4 |——O——|	0.33–0.67
Dibenzopyrrole and derivatives:		
Dibenzopyrrole	C_6H_4–C_6H_4 |–NH–|	Nontoxic
Dihydrophenazine	C_6H_4–NH–C_6H_4 |——NH——|	0.01–0.025
Phenothiazine	C_6H_4–S–C_6H_4 |——NH——|	0.03–0.05
Phenoxazine	C_6H_4–O–C_6H_4 |——NH——|	0.17–0.33
Dibenzothiophene and derivatives:		
Dibenzothiophene	C_6H_4–C_6H_4 |—S—|	0.03–0.05
Phenoxathiin	C_6H_4–O–C_6H_4 |——S——|	0.03–0.05
Phenothiazine	C_6H_4–NH–C_6H_4 |——S——|	0.03–0.05
Thianthrene	C_6H_4–S–C_6H_4 |——S——|	Nontoxic

[1] The first figure represents the concentration at which some larvae survived and the second figure the concentration that produced 100 per cent mortality.

There appears to be no relationship between the physical properties, *i.e.*, melting point, solubility, etc., of the compounds tested and their toxicity.

Compounds containing one sulfur atom in the heterocyclic ring were toxic, but the compound containing two sulfur atoms in the ring, thianthrene, was nontoxic.

Dibenzopyrrole was nontoxic, but the addition of the second imino (NH) group produced the most toxic compound included in this study, dihydrophenazine.—5-5-43.

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A Pattern of Thrips Feeding Recorded

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The characteristic scurfing on many fruits caused by thrips feeding is difficult to account for from puncturing alone, hence the explanation of some writers that there is in addition a scraping or rasping effect. In connection with certain studies on the citrus thrips, *Scirtothrips citri* (Moult.), the present writer had an opportunity to observe how this species feeds under the conditions discussed.

A spray of 3 per cent sucrose solution, dyed with acid fuchsin, was applied to a microscope slide at the rate of 10 micrograms of sucrose per square centimeter. The deposit consisted of small dried flat droplets of sucrose solution in a supersaturated state, ranging in diameter from 15 microns to 400 microns. An adult citrus thrips was confined to a small area of the deposit by a small glass cell cemented to the slide with paraffin. The slide was then placed, cell down, on the stage of a microscope and the thrips was readily observed feeding on the droplets of sucrose. The thrips placed its beak in contact with the sugar deposit, held it there for a small fraction of a second and then moved a short distance to another part of the droplet, leaving clean holes in the sugar deposit as shown in figure 1. Enough liquid is probably brought to the orifice of the beak to dissolve the sugar immediately beneath and the sugar solution is then drawn up by the thrips.

In another experiment, an almost continuous film of sucrose was deposited on a microscope slide by evaporating about 0.5 ml. of the dyed solution. An

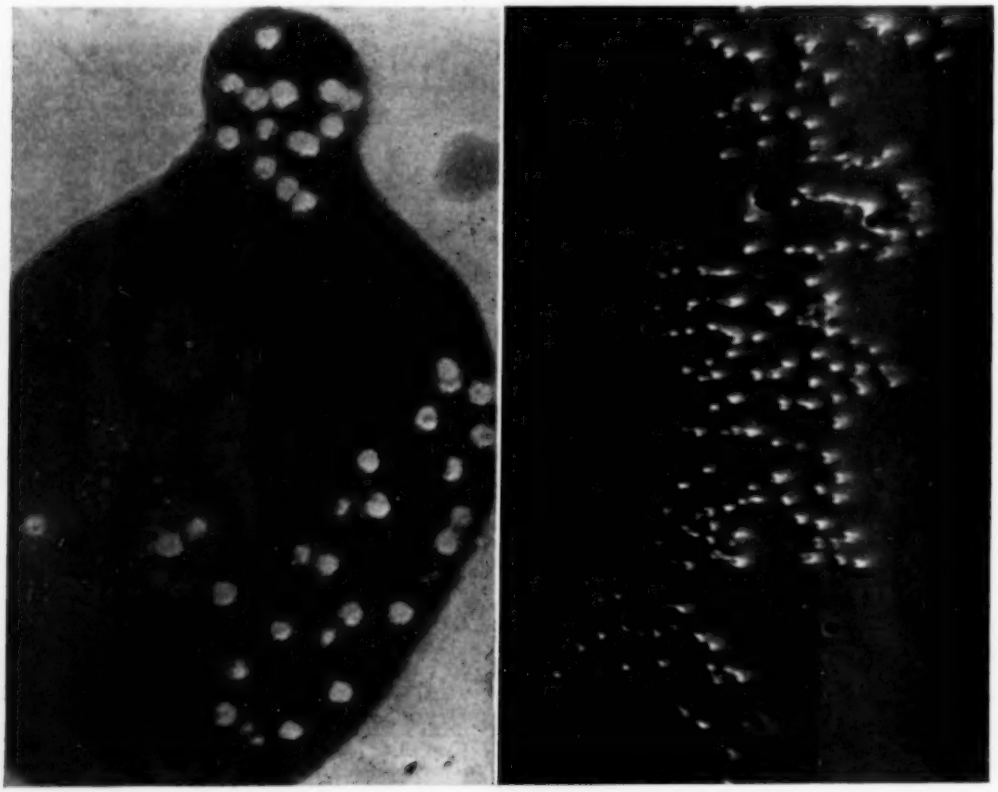

FIG. 1.—(Left) Droplet of dyed sugar deposit magnified 250 diameters, showing the holes produced by the feeding of an adult thrips. (Right).—Pattern produced by a single thrips larva feeding on a film of dyed sugar on a glass slide. Magnified 150 times. Thrips proceeded from bottom to top and produced approximately 240 holes, as shown, in 1¼ minutes.

individual thrips was placed on this film and observed under a binocular microscope. It was seen to feed in a zigzag course, producing the pattern shown in figure 2. The approximately 240 holes shown were produced in about 1.25 minutes. The holes produced by an adult thrips, as shown in figure 1, measured from 12 to 15 microns in diameter. The holes produced by the second stage larva measured 8 microns in diameter, and the holes produced by a newly-hatched larva measured 4 microns in diameter.

Under the conditions given, and from a large number of observations, it would appear that this particular species of thrips feeds by puncturing alone, since there was observed no scraping or rasping action. What might appear as due to such action is due to the highlights in the photograph, since the holes in the two pictures were the same (Fig. 1, Rt.). —3-22-43.

Naphthalene Paste

GERALD E. TRAVIS[1]

Insect pests have harassed mankind in all ages, and various methods of combatting their destructiveness have been practiced from earliest times. Fumigation with smoke and gases from burning asphalt, sulfur, and natural resins was known to the ancients. Pliny the Elder, in his *Historia Naturalis*, gives detailed directions for the destruction of fig-tree worms and flies by the use of salt water and vapors of burning galbanum.

Use of naphthalene as an insecticide apparently was first reported in 1883 by Ernst Fischer, who successfully applied it to vines attacked by phylloxera. Since that time, extensive investigations have been made of the insecticidal and fungicidal properties of this compound until it is now accepted as a powerful weapon in insect warfare.

As a fungicide, naphthalene has been found to inhibit mold development and to exterminate such fungi as *Penicillium* sp., *mucor* sp., and other species of *Mucoraceae*, *Oidium lactis*, and various Schizomycetes.

As an insecticide, it has been employed in solid or flake form, in emulsion, as a spray, and as a vapor for fumigating purposes.

In the form of chips or flakes, Glen & King (1938) have found naphthalene most effective in controlling wireworms, while Thompson (1930) has successfully used it in combatting onion, carrot, and cabbage maggots.

Pepper (1937) has employed a carbon disulfide naphthalene emulsion to exterminate wireworms without plant injury.

Spraying a solution of naphthalene in orthodichlorobenzene onto a hot surface has been reported by Sullivan and coworkers (1941) as a positive method for exterminating house flies and cockroaches.

Naphthalene vapors have been extensively employed as a fumigant. Hartzell & Wilcoxon (1930) have found this a means of controlling red spider mites, cyclamen mites, and thrips. Lehman (1930) has found it to be 10 to 14 times more effective (at the same concentration) than paradichlorobenzene against the flour beetle, *Tribolium confusum*. Flint & McCauley (1937) have reported one pound of naphthalene per 20 cubic feet of space sufficient to give complete protection against carpet beetles, clothes moths, and cigarette beetles. Hartzell (1926) has further reported that naphthalene fumigation may safely be carried out in greenhouses without fear of plant injury.

While the value of naphthalene as both insecticide and fungicide has been demonstrated, a major objection to its use in the past has been the cumbersome and rather costly methods of application. Realizing this, The Barrett Company (now The Barrett Division, Allied Chemical & Dye Corporation) developed a stable aqueous suspension of naphthalene in paste form which is readily dispersed in water and was used successfully as an insect spray. The following information on this development is published with the thought that it may be helpful where the use of naphthalene as an insecticide is indicated.

The wetting of a material like naphthalene is facilitated by use of certain vegetable gums, such as gum arabic and gum tragacanth, as well as by certain animal derivatives as gelatin, glue, and casein and by such usage may be placed in aqueous suspension. In this condition, however, rapid and objectionable settling takes place. To overcome this, a bodying agent such as bentonite or clay having high colloidal properties may be used. When using bentonite for this purpose, tendency toward flocculation on dilution of the suspension may be averted by the addition of ammonium sulfate.

A typical formula for a desirable naphthalene suspension from the standpoint of simple preparation, aging, effectiveness as an insecticide is as follows:

Naphthalene (chipped)	25.00 per cent
Glue[1]	0.30 per cent (min.)
$(NH_4)_2SO_4$	0.15 per cent (max.)
Bentonite[1]	3.00 per cent
Water	71.55 per cent

While this formula is considered optimum for most uses, the ingredients may be varied to suit specific consistency requirements.

The equipment used in preparing the suspension consisted of a Charlotte-type colloid mill connected with a circulating tank with forced feed for circulation through the system. The tank proper was provided with agitating means to insure uniformity of mixture in the earlier stages of mixing.

Water equal in weight to the total naphthalene to be used was charged to the system followed by the glue. This was circulated through the system to insure thorough dispersion of the glue with a wide setting on the colloid mill (0.005 inch). Naphthalene was then charged and circulated with gradual reduction in mill clearance to 0.001 inch until smooth; the balance of water was then added and was followed by the bentonite. After sufficient time had elapsed to smooth out the product, the ammonium sulfate was added, mill setting reduced to 0.0005 inch, and the product discharged.

In certain types of mixture, bacterial growth may occur, depending upon the amount of glue present. To control this condition, one of the better known preservatives, *e.g.*, sodium benzoate, thymol, phenol, or parachlorometacresol may be used. None of these preservatives has been observed to have any physical effect on the resulting paste.

The paste is readily dispersable in water for application by a hand or power sprayer. For some purposes, a dilution of one gallon of paste to fifty gallons

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[1] Armour's Pearl Grade glue and Rubber Grade "B" Bentonite (99 per cent passing 325-mesh sieve) have proven satisfactory.

of water has been effective. However, the proper dilution, rate and time of application will vary in order effectively to destroy the pests and at the same time not injure the vegetation. This information must be developed by the user for each specific case.

However, in many cases where naphthalene is specifically known to destroy insects, naphthalene paste may be used as an economical, easy, and effective form for applying it.—4-16-43.

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Additional Notes on Host Plants of the Pink Bollworm in Texas and Mexico

L. C. FIFE and IGNACIO MORENO,[1] *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*[2]

Three species of malvaceous plants, *Hibiscus esculentus* L., *Malvariscus drummondi* Torr. & Gray, and *Pseudabutilon lozani* (Rose) Fries, were reported by Bibby and Moreno (1941) as host plants of the pink bollworm, *Pectinophora gossypiella* (Saund.), in the Lower Rio Grande Valley of Texas and Mexico. Additional observations on these three hosts in the same area, as well as on two other malvaceous plants, *Abutilon trisulcatum* (Jacq.) Urban and *Hibiscus syriacus* L., are briefly discussed in the following notes.

Infestations have been found in the green and dry pods of okra, *Hibiscus esculentus*, on both sides of the Rio Grande only during the period August to December each year from 1939 to 1942. In the fall of 1939, 21 garden and commercial plantings of okra were examined in Willacy County, 57 in Hidalgo County, and 169 in Cameron County, and the proportions of plantings infested were 0, 12.3, and 23.1 per cent, respectively. The pink bollworm infestation in cotton was very light in Willacy County but considerably heavier in Hidalgo and Cameron Counties. During the 4-year period the highest green pod infestation in any one planting was 28 per cent (100 pods examined), but the average was less than 1 per cent. The highest infestations in okra occur in plantings adjacent to or not far distant from heavily infested cotton.

Examinations of the blooms and pods of *Malvariscus drummondi* resulted in the finding of 1 pink bollworm in 1939, 55 in 1940, 1 in 1941, and 77 in 1942. Only a limited number of observations were made in 1939, but in each of the 3 succeeding years large numbers of fruiting forms of this mallow were examined or placed in cages to determine the presence of pink bollworms. In 1941 the pink bollworm infestation in cotton was much lighter than in 1940 or 1942, and this no doubt explains the differences in results. Infestations in this plant have been found on both sides of the Rio Grande and only during the period September to December. As is the case with all the known secondary host plants in this area, except okra, infested blooms and pods were always found to be adjacent to or not far distant from infested cotton, and the average infestation never exceeded 0.5 per cent.

Two pink bollworms were found in the fruiting forms of *Pseudobutilon lozani* in 1940, none in 1941, and 15 in 1942. Of the 17 specimens, 3 were reared as moths, 2 mature larvae were taken from green pods, and 12 mature larvae were taken from dry pods, all being found in November or December. The presence of mature larvae in the dry pods would indicate that they were in the resting stage and therefore a possible source of carryover of the pink bollworm from one cotton crop to the next.

A new host was recorded when three mature pink bollworm larvae were found during the examination of a sample containing approximately 1965 green seed pods of *Abutilon trisulcatum* in November 1942. This native shrub is one of the most common of all the wild mallows in this area. It is found in well drained waste land, along river banks, old river beds, fence rows, irrigation ditches and almost any place where water does not stand for an extended period. The plant grows from 2 to 10 feet in height, bearing numerous branches and fruiting forms. The seed pods are about 0.37 inch in length and approximately 0.25 inch in width, with usually five carpels. Cory & Parks (1937) record its distribution as southern Texas, south of Corpus Christi and approximately as far west as Eagle Pass. In addition to Texas, it has been recorded by Standly (1923) from Sonora to Tamaulipas, Yucatán, and Guerrero, Mexico, as well as from Cuba and Nicaragua.

Four pink bollworm larvae were taken from the buds and blooms of the well-known ornamental

[1] F. F. Bibby, A. J. Chapman, C. A. Richmond, and Ivan Shiller, of the Brownsville, Texas, laboratory of the Bureau of Entomology and Plant Quarantine, assisted in investigations reported in this paper. The determinations of the pink bollworm were verified by Carl Heinrich of the Division of Insect Identification. Determinations of the plants were verified by botanists of the Bureau of Plant Industry, Soils, and Agricultural Engineering, of the United States Department of Agriculture and by Dr. Ira L. Wiggins of Stanford University.

[2] In cooperation with the Delegacion de Defensa Agricola of Mexico and the Texas Agricultural Experiment Station.

mallow shrubby althaea, or rose-of-sharon, *Hibiscus syriacus*, in September and October 1942. Two of the larvae were in the last instar, one in the third instar, and one in the second instar. This shrub grows from 10 to 15 feet in height, bearing many buds and blooms, although seed pods are rarely produced. This mallow is widely distributed throughout the world. In the United States Small (1913) states that it occurs "in various situations, New Jersey and Pennsylvania to Florida and Texas."

Numerous buds, blooms, and seed pods of the known hosts, *Althaea rosea* L., *Abutilon hypoleucum* Gray, *A. lignosum* (Cav.) Don, *Hibiscus cardiophyllus* Gray, *H. mutabilis* L., *H. sadbariffa* L., *H. rosa-sinensis* L., and *Malvastrum americanum* (L.) were examined, but the results were negative. *Thespesia populnea* and *Abelmoschus abelmoschus*, recorded as host plants in several other countries, are not sufficiently numerous in this area to be of any importance. The fruiting forms of many other mallows, of which about 50 species are known to occur in this area, were also examined, but no pink bollworms were found in them.—3-31-43.

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Observations on a Lepidopterous Borer in Ash

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During the early fall of 1941 it was called to the attention of the author that a white ash tree, *Fraxinus americana* L., on the college farm of the Virginia Polytechnic Institute had been severely injured by borers. The trunk and larger branches presented evidence of many adults having previously emerged, and the tree was in a rapidly declining condition. The adults obtained in late summer of the following year were identified as *Podosesia syringae* Harris,[1] family Aegeriidae.

Information was obtained on the life history of the borer by the periodical removal of larvae from the tree. About a dozen or more larvae were cut out of the tree on November 25 (1941), April 21 (1942), May 10, and at 7 to 13 days interval thereafter until early in September. Very little growth was observed to have taken place between the November and April collections. On the latter date the larvae were only about 7 to 8 mm. in length, whereas the mature larvae vary from almost an inch to more than an inch in length. The application of Dyar's rule (Dyar 1890) to the head capsule measurements of 152 larvae indicated the existence of from 6 to 8 instars. However, the number of larvae under observation, as well as their distribution among all instars, was inadequate to warrant a definite statement on this point.

The larvae were found to feed in the bark, cambium, and only superficially in the xylem during the remainder of the season in which the eggs were deposited. However, during April and May of the following year they began to penetrate more deeply into the xylem. As feeding continued throughout the spring and summer the larval burrows became larger and longer, and finally reached a depth of from $\frac{3}{4}$ to $1\frac{3}{4}$ inches in the xylem. The burrows in general followed the longitudinal axis of the tree, and those of the mature larvae attained on average size of about $\frac{3}{4}$ inch in diameter. An opening was made to the outside of the tree prior to pupation, in order that the mature pupa could be partly protruded from the tree just before the emergence of the adult. The presence of borers and their activity were indicated externally by the oozing of sap from the tree and the accumulation of great quantities of frass around the base of the tree. The maximum accumulation of frass occurred during May and June.

A total of 95 adults emerged from the tree between August 24 and September 25, 1942. The principal emergence was from September 5 to 21, during which period 84 adults emerged. The counts were made from the number of pupal skins protruding from the tree. Mating of the adults was observed soon after emergence. Thus, it follows that there is one generation each year of this borer.

The observations made by the author on the life history and habits of *Podesesia syringae* as a borer in the white ash are in close agreement with those reported by Seaver (1916). On the other hand, Forbes (1911) has reported that the adults make their appearance from the latter part of April to the middle of June in central and northern Illinois, and that the larvae usually complete their development before the following winter. He also states that the eggs are layed by preference on scars and injured places on the bark, and the resulting larvae produce large, rough, scar-like outgrowths from knots, roughened places, or wounds. This dissimilarity between the observations of Seaver and the author on the one hand and Forbes on the other, as regards the life history and habits of *P. syringae*, could hardly be accounted for by the slight variations in environmental conditions which may have existed at the different geographical locations from which the data were obtained. The author is therefore of the opinion that the observations of Forbes were either made upon another perhaps closely related species of borer, or upon *P. syringae* in a host tree other than the ash.

Many of the larvae were killed in their burrows by a fungus, *Beauveria sp.*[2] The first parasitized larvae were observed in late July, and they were found in increasing numbers during August. The excessive rainfall during the 1942 growing season was probably a factor contributing to the success of the fungus in killing a rather high percentage of the larvae.—3-22-43.

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[1] Identified by Dr. Carl Heinrich, Division of Insect Identification, Bureau of Entomology and Plant Quarantine.

[2] Identified by Dr. John N. Couch, Department of Botany, University of North Carolina.

The Common Toad as an Enemy of Blister Beetles[1]

N. P. LARSON, *South Dakota Agricultural Experiment Station, Brookings*

The common toad was observed to be abundant in irrigated gardens at Fort Thompson, South Dakota, where blister beetles were numerous and causing injury to potato and other crops during the past summer.

It is well known that toads feed to a certain extent on insects; it is also fairly well known that blister beetles are not much preyed upon by larger animals probably because of their vessicatory properties.

Two lots of 50 young toads, *Bufo americanus* Holbrook, were taken in potato fields in the evening just before dark. Toads between one and two and one-half inches in body length were hand-collected and immediately the stomachs were extirpated and preserved in 70 per cent alcohol. The two lots of stomachs were taken at Fort Thompson, July 24, and August 7, 1942, by the writer.

Subsequent examination of the stomach contents showed blister beetles to be the most common single item of food of the young toads at both of those dates, with the possible exception of aphids, which were not enumerated.

Of the 100 stomachs examined 65 were found to contain one or more blister beetles or recognizable parts thereof. Several of the beetles found were whole, others were worn or slightly broken and a few were fragmentary. The 65 stomachs contained 157 individual blister beetles, an average of 2.4 per toad or an average of 1.5 for all the stomachs examined. Twenty-seven stomachs contained only one beetle each, 16 stomachs each contained 2 beetles, 9 stomachs each contained three beetles, 7 had 4 beetles, 5 had 5 beetles, one stomach contained 7, and one contained 9 beetles. Two beetles were loose in the collecting jar and it is not known from which toads they came.

Although there were four species of blister beetles present in the potato plantings, only the two dominant species, *Macrobasis immaculata* (Say) and *Epicauta maculata* (Say), were found in the toad stomachs. *M. immaculata* included 94 of the specimens and the other 63 were *E. maculata*. The two species of beetles were found together in only 9 of the stomachs.

In the stomachs collected on July 24, 59 beetles were *Epicauta maculata*, but that species was so near the end of its season that on August 7 only 4 specimens were taken. *Macrobasis immaculata* included 21 beetles on the first date and 71 beetles at the second collection. In the field there was a proportionate decrease in numbers of *E. maculata* in the whole beetle population.

While the foregoing has been entirely on young toads, one full grown toad was opened and found to contain several blister beetles. The 1942 season was moist and was especially favorable for toads in South Dakota.

Numerous other insects were present in the stomachs examined. At the time of the first collection, aphids and Colorado potato beetles and larvae were not common, but these were abundant at the second date. Tenthredinid slugs were common on August 7 but were not found on July 24.

[1] Approved for Publication as a scientific note in the JOURNAL OF ECONOMIC ENTOMOLOGY as paper number 173 of the South Dakota Agricultural Experiment Station.

Orders of insects represented in the stomach contents included Orthoptera, Neuroptera, Thysanoptera, Homoptera, Hemiptera, Coleoptera, Diptera, Hymenoptera and one lepidopterous larva. One small spider and one mite were also found. Insects identified in the stomach contents included:

ORTHOPTERA

Locustidae—grasshoppers, adults and nymphs
Tettigoniidae—a camel cricket

THYSANOPTERA

One perfect specimen

NEUROPTERA

Chrysopidae—green lacewings and larvae; brown lacewing

HOMOPTERA

Cicadellidae—adults and nymphs
Aphididae—adults and nymphs, apters and alates. As many as 35 specimens in one toad stomach

HEMIPTERA

Scutelleridae
Cydnidae
Lygaeidae—adults and nymphs
Miridae—adults and nymphs
Reduviidae—adults and nymphs
Pentatomidae—adults and nymphs

COLEOPTERA

Carabidae—several species, adults and larvae
Mordellidae
Cucujidae
Coccinellidae—adults and larvae
Histeridae
Elateridae
Scolytidae
Staphylinidae
Curculionidae
Meloidae—the two species named above
Chrysomelidae—Colorado potato beetles and larvae
—flea beetles
—twelve spotted cucumber beetles

DIPTERA

Cecidomyiidae
Tachinidae
Muscidae

LEPIDOPTERA

One unidentified larva

HYMENOPTERA

Formicidae—winged and non-winged individuals
Tenthredinidae—adults and larvae
Andrenidae
Chalcididae
Cynipidae
Vespidae
Sphecidae

Class ARACHNIDA

One small spider
One mite

Although the collections were made about two miles from the Missouri River and less than a half-mile from two large ponds, there were no aquatic insects in the toad stomachs.—4-11-43.

Partial Replacement of Pyrethrins by Dichloroethyl Ether in Oil for Control of Corn Earworm

G. W. BARBER, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

Shortages in the supply of pyrethrum due to the war made it advisable to determine whether dichloroethyl ether could be used to replace part of the pyrethrins in insecticidal oil used for control of the earworm *Heliothis armigera* (Hbn.) in sweet corn. An investigation of this subject was made in the lower Rio Grande Valley, Tex., in April and May 1942. Mixtures containing from 0.1 to 0.2 per cent of pyrethrins and from 0.5 to 2.0 per cent of dichloroethyl ether were prepared in white oil of 125/135 seconds (Saybolt) viscosity. Treatments of 25 ears per material were made in each of 3 fields of Ioana sweet corn approximately one week before roasting-ear harvest, which provided a severe test of the efficiency of the mixtures. The oil was applied to the interior silks in the usual manner at a dosage of 0.75 cc. per ear by use of a force oiler. Ears in the three fields were treated on April 26, April 30, and May 8 and were examined at time of roasting-ear harvest on May 5, 10, and 14, respectively.

The results of these treatments, as judged by the percentage of the larval populations killed and by the percentage of ears containing no living larvae at time of harvest, are given in table 1. The results by both criteria show that a combination of 2 per cent dichloroethyl ether and 0.1 per cent of pyrethrins gave protection superior to, and a combination of 1 per cent of dichloroethyl ether and 0.1 per cent of pyrethrins or 0.5 per cent dichloroethyl ether and 0.15 per cent of pyrethrins gave protection equal to that obtained by use of 0.2 per cent pyrethrins or 2 per cent dichloroethyl ether alone in oil. At the prevailing prices of pyrethrum extract and dichloroethyl ether any of the combinations mentioned would involve a substantial saving in the cost of materials for treatment per acre over the cost of the usually recommended 0.2 per cent pyrethrins in oil. The actual use of the combinations described will depend on whether dichloroethyl ether is available as an insecticide.—5-5-43.

Table 1.—Effectiveness of combinations of pyrethrins and dichloroethyl ether against earworms in three fields of Ioana sweet corn in the Lower Rio Grande Valley, Tex., 1942. Twenty-five ears were treated per field per material.

Dichloroethyl Ether, Per Cent	Pyrethrins, Per Cent	Percentage of Larvae Killed				Percentage of Ears Containing No Living Larvae			
		Field 1	Field 2	Field 3	Average in all fields	Field 1	Field 2	Field 3	Average in all fields
2.0	0.20	93.3	100.0	96.4	96.5	88.0	100.0	96.0	94.7
	0.15	90.5	96.9	92.3	93.0	84.0	96.0	92.0	90.7
	0.10	93.6	95.7	100.0	95.8	84.0	92.0	100.0	92.0
	none	89.7	90.9	88.0	89.7	84.0	88.0	88.0	86.7
1.0	0.20	87.8	90.0	100.0	91.3	84.0	84.0	100.0	89.3
	0.15	93.0	94.4	80.8	90.5	88.0	92.0	84.0	88.0
	0.10	89.1	81.6	96.9	88.8	80.0	76.0	96.0	84.0
0.5	0.20	89.5	80.9	95.4	87.2	84.0	68.0	96.0	82.7
	0.15	90.3	79.6	94.7	86.2	88.0	68.0	96.0	84.0
	0.10	74.5	84.2	77.8	78.4	52.0	76.0	84.0	70.0
None	0.20	92.9	87.3	92.9	89.1	64.0	80.0	92.0	81.3
	0.15	94.9	75.6	88.5	85.9	92.0	64.0	88.0	81.3
	0.10	74.4	87.5	95.7	84.3	72.0	88.0	96.0	85.3
None (check)	None	0	0	0	0	0	0	16.0	5.3

James R. Henry, formerly employed by the Division of Cotton Insect Investigations in the Bureau of Entomology, has become an Air Cadet having previously graduated as a sergeant in the Aviation Gunnery School at Harlingen, Texas.

Mr. Henry's present address is:

Group 9, Sqdn. 1, Flight E,
882d P.T.S., S.A.A.C.C.,
San Antonio, Texas.

Dr. V. B. Wigglesworth, well-known insect physiologist of the London School of Hygiene and Tropical Medicine, has been appointed Director of a new Unit of Insect Physiology under the British Agricultural Research Council. He continues to work in the London School of Hygiene and Tropical Medicine, Kepper Street, Gower Street, London, W.C.1. Dr. Wigglesworth will be pleased to receive reprints from American entomologists on insect physiology, toxicology, and ecology.

Dr. John M. Hutzel, instructor in Entomology at Ohio State University, and Agent with the Bureau of Entomology and Plant Quarantine for the past two summers, has been appointed an Ensign in the U. S. Naval Reserve. He is a malariologist, in training at the Naval Medical Center, Bethesda, Md.

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Entomological Training for the Armed Forces[1]

THERE IS NO DOUBT that Entomology is a science as important and critical in war times as engineering, agriculture, medicine, chemistry, physics or bacteriology. All who have studied the matter carefully recognize that insects are man's greatest competitors or enemies, even in peace times. In the stressful times of war they become vastly more important and present grave threats to the existence of millions of people. In at least five of our vital war-time efforts, insects constitute one of the greatest obstacles to our success.

First, in connection with the program for increased food production. Other efforts in this program are likely to be disappointing, wasteful exertions, unless as careful attention is given to controlling the *negative* factors of production such as predicting, preventing and destroying insect outbreaks, as to the *positive* factors, such as proper planting, fertilizing and cultivating.

The *second* war effort to which insects stand opposed with tremendous power is the production of essential plant fibers, wool, and hides; and the health, efficiency and productive capacity of all of our domestic animals, whether grown as a source of meat and eggs, of leather and wool, or as beasts of burden.

Third, we must not only produce, we must also protect all kinds of stored foods and feeds, fibers, timbers, paper stocks and records, and other organic supplies to which insect attacks are as great a hazard as fires.

Fourth, and most essential, is the protection of both our military and civilian personnel from annoyance, reduction of efficiency, illness and death resulting from the diversified and devastating attacks of thousands of kinds of insects and the deadly diseases they disseminate. There are no worse places in all the world where deadly insect-borne diseases flourish than tropical Africa, the Mediterranean countries, the islands of the Pacific, India and China. There, death from sleeping sickness, bubonic plague, malaria, typhus, relapsing fevers, yellow fever, Asiatic cholera, typhoid and disenteries, sand-fly fever, oriental sore, yaws, and other diseases absolutely dependent upon insects for transmission from person to person, as well as unspeakably loathsome parasitic worms, lice and ticks, present a menace to our troops, as real as the attacks of Nazi, Nipponese or Italian troops.

In the *fifth* place, we must safeguard this continent from grave menaces to our present and future welfare by the introduction of new pests, which have never gained a foothold in this country. Other parts of the world are teeming with many serious insect pests of crops, parasites of animals and man, and disease-carrying insects, which we have never had to fight. The present greatly increased traffic, especially from countries not formerly important to American commerce, presents a grave menace, calling for adequately trained entomologists to forestall.

Still another reason for encouraging more training along entomological lines is the real threat of entomological and biological warfare; that is, the intentional spread by our enemies of destructive insect-vectors of human and animal diseases or direct pests of crops and store products. Since the Japs have already attempted to start epidemics of bubonic plague in China, it is obvious that we should provide men well trained in medical and veterinary entomology and insect control to check any such outbreaks that may be started by our enemies. The possibilities of entomological warfare are extremely potent. By distributing crop pests not now present in any territory upon growing crops; by showering pests of stored products over food depots and cities; and by the purposeful spreading of living insect-carriers of highly-fatal human diseases, crops could be ruined, stored products devastated, and human lives endangered to a greater extent than by direct human attack.

[1] Copy of a letter addressed to the "Committee on Coordination of Entomology with the War Effort," published with the permission of the writer.

In all past wars deaths from epidemics of insect-borne diseases have generally exceeded deaths from enemy bullets, bombs or bayonets. The insect menace in the present war we believe presents a problem second only to the necessity of supplying our armed forces with food and munitions.

Unfortunately there is a widespread erroneous assumption that medical men and bacteriologists are all that are needed to protect our troops from diseases. But the worst diseases are those which are dependent upon insects for dissemination and for which the most effective control is the destruction of the insect carriers. Inexcusably, medical and premedical curricula do not generally include training in medical entomology and insect control. Consequently entomologically trained men must be engaged to aid physicians and sanitary engineers, by discharging the duties of recognizing and controlling dangerous insects, for which they alone will be qualified and competent. The British, because of their long and intimate contact with tropical insect-borne diseases in Africa, India, Malay, and other of their colonies, appreciate the importance of medical entomology vastly more than our administrators and physicians do. I understand that every British expeditionary unit includes some trained entomologists, usually two for each 100 troops. I hope that our military men will awake to this necessity before it is too late. Insect control under war conditions presents so many problems that cannot even be anticipated that only broadly and technically trained men, alert to the probable and versatile attacks of these six-footed enemies can be depended upon to meet such emergencies.

Thorough inspection of incoming and outgoing troops and prisoners of war to make sure that they are not conveying dangerous pests in their baggage or upon their persons; protection of our food supplies both from contamination with disease organisms spread by insects and from waste due to infestations by insects; advice and guidance in the location and building of camps and cantonments to avoid attacks by mosquitoes, tse-tse flies, lice, ticks, chiggers, black flies, sand flies, termites, cockroaches and other serious pests; the proper disposition of camp refuse to avoid contamination of foods by house flies—those are a few of the important duties, in addition to the destruction of infestations of mosquitoes, lice, fleas, bed bugs, ants, termites, cockroaches, etc., which only men having entomological training can perform.

For reasons outlined and others which are at once suggested to any informed entomologist, I have a strong conviction that entomological training is essential to the national health and safety and to our efficient and successful war efforts. If the profession of Entomology is to meet its opportunities and obligations, it is imperative that recognition be given to the fact that the present supply of entomologists fails to equal the demands of these abnormal times. In view of these obvious needs, it is suggested and recommended that your Committee take immediate steps to include in your program any and all of the needs indicated which have not yet been foreseen, and that there be formed such sub-committees of other groups as may be indicated, to the end that representations may be made promptly to those in authority in the various branches of the government service, so that they may be brought to a realization of these needs, and so that they may be led to give approval to plans which will result in a training of added entomological personnel to meet these needs. Because these needs may be more obvious to persons associated with entomological work than to those to whom such work is foreign, it would seem folly to wait until these situations become more acute than at present. Those of us engaged in entomological work are powerless to take effective steps to meet these needs until the needs are better appreciated by those directly responsible for the military and civilian prosecution of the war effort. This, then, means that it is incumbent on the profession to make its potentialities known.

If a program can be evolved to further the war effort through more effective training of entomological personnel, the facilities of the Department of Entomology in our institution are available for whatever added effort may be assigned us.—12-11-42.

C. L. METCALF,
Professor of Entomology, Univ. of Illinois

OBITUARIES

William Hunter Volck
1879-1943

William Hunter Volck, entomologist, chemist, and inventor of insecticides, was born at Riverside, California, September 24, 1879, and died at his home at Watsonville, California, January 12, 1943. He was the son of Stephen Volck, M.D., of Riverside and Long Beach, California, and the grandson of William Hunter, D.D., Professor of Divinity of Allegheny College and writer of many familiar hymns. He was reared on a citrus farm and educated in the public schools of Riverside and Long Beach. He entered the College of Agriculture, University of California, in 1901, but did not graduate.

At the suggestion of Professor C. W. Woodworth, in 1902 he was appointed an inspector of the Los Angeles County Board of Horticultural Commissioners to make a study of the life history of the red spider of citrus trees and its control. This was the first real study of this mite in California and the

results were published by Professor Woodworth.[1] Volck also received a similar appointment by the County Board of Horticultural Commissioners of Sutter County to study the red spiders on both citrus and deciduous fruit trees. He found that sulphur dusts and sprays offered best possibilities of control (Woodworth, Bul. 154, 1903).

In 1902, Professor Woodworth also appointed Volck as his assistant and sent him to southern California to study the biologies and control of citrus insect pests. Volck made a thorough study of the various sprays, chiefly oils, used by the orchardists, for the control of black scale in particular, but also soft brown scale, red scale, and purple scale on citrus trees. His conclusions were published in Bulletin 153 of the California Agricultural Experiment Station in 1903 and may be summarized in his own words: "The emulsions made from California oils have not usually been as satisfactory as those from eastern kerosene, and a large amount of damage has been done by separated oil, which rises to the surface in spray tanks . . . the emulsions have proved unsatisfactory primarily because of the difficulty of obtaining a stable article . . . while the mechanical mixing idea preceded the emulsions, it is only in recent years that it has been perfected and made practicable. Mechanical mixing represents the most modern idea in practical spraying and is certainly a great improvement over the 'stable' emulsions, which are so only in name." This beginning in the use of oil sprays served to stimulate his efforts throughout the rest of his life towards the perfection of stable mineral oil emulsions. His complete success is evidenced by the many types of oil emulsions he perfected, and one of the white oils which bears his name "Volck" has had world-wide recognition as an important insecticide.

His next important beginning had to do with the substitution of lead arsenate for paris green in California orchard practice in the control of the codling moth. In 1905 he published his "Practical suggestions for codling moth control in the Pajaro Valley" (Calif. Agr. Exp. Sta. Cir. 14) in which he recommended:

(1) That paris green be discarded in all sections where its careful use had caused injury to the trees.
(2) That lead arsenate, since it had been found reliable and non-injurious to vegetation, be substituted.
(3) That the commercial lead arsenate is preferable to the home-made products.
(4) That lead arsenate may be improved in retention or rain resistance by adding some adhesive.

These investigations also had far reaching results in the improvement of the regular or so-called acid, standard, or diplumbic lead arsenate; the use of adhesives; and the invention and production of triplumbic or basic lead arsenate later on in 1907.

He also served as field assistant in entomology with the University of California from 1908–1913. During this period he worked on apple insects in the Watsonville district and wrote the splendid life history and control of the California tussock moth in 1907 (Calif. Agr. Exp. Sta. Bul. 183).

In 1907 and 1909 he acted as Entomologist of Santa Cruz and Monterey counties. Beginning on this period he prepared a series of at least nine small press bulletins, published at Watsonville, on the control of insect pests and diseases of the apple and pear. From 1911–1920 he was appointed County Horticultural Commissioner of Santa Cruz County. With W. S. Ballard he published a press bulletin on powdery mildew of apple in 1912 (Bul. 9) and a bulletin on the same subject in the United States Bureau of Plant Industry (Bul. 120) in 1914. He also published a number of important articles in the Monthly Bulletin of the California State Horticultural Commission on summer pruning of the apple and control of the potato tuber moth (Vol. 3, 1914), and the apple leaf-mining case-bearer (Vol. 6, 1917) which bears his name, *Haploptillia volcki* (Heinrich).

In 1920 he resigned his county position to become research director of the California Spray-Chemical Company, a corporation originally formed by Pajaro Valley apple growers and a few others to manufacture and make available for use some of Mr. Volck's inventions: the new types of diplumbic or acid lead arsenate and triplumbic or basic lead arsenate, already referred to. In this capacity he also directed laboratories of the company in the states of California, Florida, New Jersey, and Washington as well as in several foreign countries. In 1915 he was presented with a gold medal for achievements in chemistry by the Pan-Pacific International Exposition at San Francisco. In 1915 he was married to Helen Haynes, who survives him.

He was granted many patents relating to insecticides. His most important patent inventions have been summarized by Leo R. Gardner as follows:

1907, Three patents were applied for by Mr. Volck and granted him as co-inventor, covering a method of manufacturing lead arsenate. This method became more or less world-wide and is in general use throughout the United States at this time. 1911, A new method of manufacturing lime-sulfur solution. This patent was followed in 1922 by still another new method for the manufacture of this product. 1921, A method for the recovery of alkaloids such as strychnine from the seeds of *Strychnos Nux-vomica*. 1923, Oil-sulfur dust, a product now used especially in certain eastern states. 1924, Completion of the final work of laying the foundation for the five basic phytonomic oil patents. Such oil sprays are now widely used throughout the fruit-growing areas of the world. 1929, Conclusion of two studies which were the basis for patents on balanced emulsions and the use of oils as plant stimulants. At about this time also the work on the manufacture of wetting agents from petroleum oils was concluded. 1932, Invention of a dust suitable for the application of oils sprays in dust form. He also concluded the work on balanced oil emulsions, correcting the water so as to give uniform behavior in the spray tank. Concluded investigations on weed killers, chief of which is a product with petroleum oil base. 1933, Conclusion of investigations on methods of refining petroleum oils, and in particular selective solvent methods for the refining of tree spray oils. 1934, Produced a new, spreader and depositor still in general use. 1934–35, Two inventions of a new type of soluble spray oils. 1935, A stabilized nicotine agricultural spray. 1938, A mixed garden dust comprising a water insoluble inorganic fluorine and a copper zinc silicate complex.

Throughout the years Mr. Volck had continuously worked on the many subjects which were both his profession and his hobbies.

[1] Bulletin 145, California Agr. Expt. Sta. 1902.

After his return from the Hawaiian Islands, where he investigated the control of the pineapple mealybug in 1931–32, he was much interested in growing tropical plants in his greenhouse and was specially concerned with hybridizing species of *Colias*. He also developed water cultures. In the last five years he made additional advancements in lead arsenate which even surpass his first efforts. He also collaborated in the development of many new products and processes with other technical workers under his direction, remaining very active in his technical capacity throughout his life.

He was a member of the American Association for the Advancement of Science and of the American Chemical Society and, while he did not join entomological societies, he often attended meetings and contributed to the programs. He was elected a Fellow of the Royal Society of Arts, Manufacture, and Commerce, London.—3-15-43.—E. O. ESSIG, *Berkeley, California.*

William Albert Hoffman
1894-1943

Bent down over his desk as though asleep, the body of Dr. Wm. A. Hoffman was found Sunday morning, April 4th, in his laboratory at the Columbia University School of Tropical Medicine at San Juan, Puerto Rico. It was the final release from the physical limitations that his keen mind had sought in vain in the past, for an attack of infantile paralysis in his youth had crippled one leg so that it was entirely useless below the knee. As partial compensation, he had exceptional strength of arms, which became legendary when as a student at Cornell he could throw a baseball farthest, besides taking an active part in bowling and swimming. Descending a long straight stairway, he grasped the balustrade with his hands and slid gently to the bottom, a seemingly physical impossibility that he managed with ease. He played the Cornell chimes, although nobody was admitted to the library tower to see how he did it. Such bells are not available elsewhere, and his violin formed an outlet of expression and consolation always at hand.

His first employments, as teaching fellow at Iowa State College, and as scientific assistant in the Bureau of Entomology of the U. S. Department of Agriculture, left no mark in published literature, although his observations on the food of the yellow perch in Cayuga Lake were published by the Iowa Academy of Sciences at this time. His first publication when assistant to the State Entomologist of New York, a note on the method of penetration of the larvae of bot flies, already indicated the later trend of his major interests, although he was primarily concerned at this time with flea-beetles (Chrysomelidae). He was assistant medical entomologist at Johns Hopkins from 1921 to 1924, presenting for his doctorate thesis a review of *Culicoides* for North and Central America and the West Indies. The following period, of less than two years, in Haiti in a survey for the International Health Board of the Rockefeller Foundation, saw the release not only of his mental energies, as shown by the greatest number of independent publications, but also at least in part from physical limitations. The new automobile, for practical purposes, was controlled entirely by his hands and arms, and fortunately so. An initial trip to which he invited the Botanist Ekman and Pharmacist Buch, up, and *down* Morne Cabrit, by the crooked, boulder-strewn road Smedley Butler's Marines had built, failed to result in disaster when the brake-bands ceased to hold merely because he had the physical strength to steer accurately and keep the car to the road. No amount of determination, however, will prevent thorns puncturing tires, and the writer recalls an entire afternoon repairing and changing them in the shadow, but not in the shade, of Ft. Nationale. The summit was reached in time to see the sun set over Port-au-Prince harbor.

Not finding sufficient scope for all his energies in official activities, Dr. Hoffman wrote to the U. S. National Museum, offering to cooperate in any field suggested. A few months later one of their specialists arrived in Port-au-Prince looking for the eager collaborator. Unfortunately, he didn't know the name of the person he was looking for, as the girl who filed the letter originally later couldn't remember the name—nor could anyone else at the Museum. Such gestures of cooperation, however, were more than gestures, and indeed the larger part of the information concerning material collected by Dr. Hoffman, not only then but later in Puerto Rico, appeared as new records or descriptions by others of new species collected by him.

Becoming assistant professor of parasitology at the School of Tropical Medicine at San Juan in 1926, unfortunately for entomology, caused a major diversion of his interest to investigations of schistosomiasis, and to cooperation in the projects of his colleagues in other fields. Vacationing or week-ending in the mountains, he collected assiduously for others, but the notes he wrote concerned the insects that came to him at the School: *Eufalia unicostata* on the walls of his laboratory, *Rhizopertha dominicana* in the books of the School library, and *Icerya purchasi* on the casuarina hedge in the patio.

Within the past few months he was being considered for heading a new school of tropical medicine at Belem, Para, Brazil, and only his physical limitations had prevented immediate acceptance. It is Brazil's loss, as well as that of taxonomists, entomologists and numerous friends, that he was prevented from entering the region where Bates and Goeldi pioneered.

G. N. WOLCOTT

MISSISSIPPI STATE COLLEGE ENTOMOLOGY GRADUATES AND PERSONNEL IN THE ARMED FORCES

Major J. H. Adams

J. H. Adams, '26, with the Pink Bollworm Control Division, B.E.P.Q., is now a major in the infantry and is stationed at Fort Huachuca, Arizona.

First Lieutenant Robert W. English

Robert W. English, '39, is now a first lieutenant in the Army Air Corps and was recently awarded the Air Medal with two oak leaf clusters for heroic action in North Africa. Before entering the service, he was engaged in sanitary engineering and malaria control by the Warren County Health Department, Vicksburg, Mississippi. He had previously been employed in white-fringed beetle control and eradication.

Chief Pharmacist's Mate F. F. Bibby

F. F. Bibby, '14, recently with the Division of Cotton Insect Investigations, B.E.P.Q., is now chief pharmacist's mate at the U. S. Naval Hospital, Pensacola, Florida.

Captain Hunter H. Kimball

Hunter H. Kimball, x'17, former chief inspector of the State Plant Board of Mississippi, is now a captain at Headquarters Base Sec. 3 in Australia and may be addressed A.P.O. 923, care of Postmaster, San Francisco, California.

Lieutenant (j.g.) Ross E. Hutchins

Ross E. Hutchins, M.S. '31, Associate Professor of Zoology and Entomology at Mississippi State College, is now a lieutenant (j.g.) in the Navy. He may be addressed care of the dispensary, Armed Guard School, U. S. Naval Reserve, Gulfport, Mississippi.

Captain Lester Bridges

Lester Bridges, '37, of the Sweetpotato Weevil Project, B.E.P.Q., has been serving as captain at Fort Benning, Georgia, but was recently transferred to the Army Air Corps at Maxwell Field, Alabama where he is taking pilot training.

Captain Curtis H. Adams

Curtis H. Adams, '41, formerly employed by the State Plant Board of Mississippi and also by the Bureau of Entomology and Plant Quarantine, is now a captain in the Army and was last heard from at Belton, Texas.

Second Lieutenant Willie R. Smith

Willie R. Smith, x'42, formerly employed in the Division of Cotton Insect Investigations, B.E.P.Q., is now a second lieutenant in the Army Air Corps assigned to the transport service. At present, he is with the 100th Headquarters and Air Base Squadron Alpena, Michigan.

Second Lieutenant Elmo F. McClain

Elmo F. McClain, '40, was a graduate student in entomology at North Carolina State College when he went into the service. Lieutenant McClain is now a bombardier on a Flying Fortress and was last heard from at Cut Bank, Montana.

Lieutenant (j.g.) Thomas W. Ramsay

Thomas W. Ramsay, '40, formerly employed by the White-Fringed Beetle Control Project, B.E.P.Q., has the rank of lieutenant (j.g.) in the U. S. Naval Air Corps. Lieutenant (then Ensign) Ramsay was recently awarded the Navy Cross for heoric action in the battle of Midway, in which he brought down some Jap planes, was shot down himself and floated for several days before being rescued.

Lieutenant (j.g.) Elon E. Byrd

Elon E. Byrd, B.S. '29, M.S. '31, a member of the Zoology Department of the University of Georgia for the past several years, recently accepted a commission as lieutenant (j.g.), U. S. Naval Reserve and was presumably in the South Pacific when last hard from.

Lieutenant Roy W. Burnham

Roy W. Burnham, '41, formerly employed in research on the white-fringed beetle by the Bureau of Entomology and Plant Quarantine, was a lieutenant at Camp Edwards, Massachusetts when last heard from.

Second Lieutenant J. K. Atkins

J. K. Atkins, '42, a graduate in entomology, is now a second lieutenant of Company M, 38th Inf., Camp McCoy, Wisconsin.

Major George F. McLain

George F. McLain, '25, in charge of the Phoenix, Arizona office of the Division of Pink Bollworm Control, B.E.P.Q., is now a major in the Army at Camp Claiborne, Louisiana.

Sergeant J. R. Henry

J. R. Henry, '41, formerly employed by the Division of Cotton Insect Investigations, B.E.P.Q., recently graduated as a sergeant in the Aviation Gunnery School at Harlingen, Texas.

Staff Sergeant K. H. Applewhite

K. H. Applewhite, '39, employed by the White-Fringed Beetle Control Project, B.E.P.Q., at New Orleans, Louisiana, is a staff sergeant in the officer candidate school at Fort Benning, Georgia, and expects to receive his lieutenant's commission in July.

Lieutenant G. W. Haug

G. W. Haug, M.S. '31, formerly employed by the State Plant Board of Mississippi, is now a lieutenant of the First Rocky Mountain Rangers at Camp Nanaimo, British Columbia.

First Lieutenant C. A. Wilson

C. A. Wilson, '40, has been commissioned as a first lieutenant in the U. S. Public Health Service and is now stationed at Little Rock, where he is State Entomologist in charge of malaria control in war areas in Arkansas.

Sergeant W. M. Carter

W. M. Carter, B.S. '38, M.S. '39, formerly em-

ployed by the White-Fringed Beetle Control Project, B.E.P.Q., is now a sergeant in the Medical Corps, Base Infirmary, Gieger Field, Washington.

PHARMACIST'S MATE WOODROW O. OWEN

Woodrow O. Owen, '39, formerly in charge of white-fringed beetle work, B.E.P.Q., Baton Rouge, Louisiana, is now pharmacist's mate second class, U. S. Naval Reserve, located at the Post Dispensary, Marine Barracks, Parris Island, S. C.

PHARMACIST'S MATE J. H. BREAZEALE

J. H. Breazeale, '40, recently employed in research on the white-fringed beetle with the Bureau of Entomology and Plant Quarantine at Florala, Alabama, is now pharmacist mate third class, U. S. Naval Reserve, Area 4 Dispensary, Camp Lejeune, Hadnot Point, New River, N. C.

LIEUTENANT (j.g.) J. B. HULL

J. B. Hull, '30, of the Division of Insects Affecting Man and Animals, B.E.P.Q., at Fort Pierce, Florida, is now a lieutenant (j.g.), U. S. Naval Reserve in the Malaria Control Laboratory, Marine Barracks, Hadnot Point, New River, N. C.

SECOND LIEUTENANT WILLIAM ROY WEST

William Roy West, graduate assistant in entomology at Mississippi State College in 1942, was commissioned a second lieutenant in the Marine Corps in January and is now a member of "H" Co., 2nd Bn., 24th Marines, Camp Pendleton, Oceanside, California.

CAPTAIN SAM O. HILL

Sam O. Hill, '29, with the Bureau of Entomology and Plant Quarantine at Monticello, Florida, is now a captain in the Sanitary Corps and is assistant camp medical inspector at Camp Stewart, Georgia.

FIRST LIEUTENANT W. D. REED

W. D. Reed, '22, in charge of Stored Tobacco Insect Investigations, B.E.P.Q., Richmond, Virginia, is now a first lieutenant in the Chemical Warfare Service at Post Headquarters, Edgewood Arsenal, Maryland, in charge of sanitation and pest control work.

MAJOR JAMES M. MCGOUGH

James M. McGough, '28, formerly employed in the Division of Foreign Parasite Introduction of the Bureau of Entomology and Plant Quarantine and later with the White-Fringed Beetle Control Project, is now a major in the Army and is presumably located somewhere in Africa. He may be addressed at A.P.O. 616, care of: Postmaster, New York City.

PHARMACIST'S MATE F. T. MCGOUGH

F. T. McGough, '32, formerly engaged in commercial pest control in New Orleans, is now a pharmacist's mate second class and at present is a patient in the U. S. Naval Hospital at Pensacola, Florida.

CORPORAL J. E. RAGLAND

J. E. Ragland, x'40, formerly employed by the State Plant Board of Mississippi as apiary inspector, is now on foreign service and is a corporal of the 3rd Prov. Ord. Co., Amm., A. P.O. 635, care of: Postmaster, New York City.

PRIVATE CALTON HOWELL

Calton Howell, x'34, employed for several years by the Stoneville Laboratory of the Division of Cotton Insect Investigations, B.E.P.Q., is now a private in the Army and is stationed at Pyote, Texas.

SERGEANT O. E. HUNT

O. E. Hunt, '40, formerly employed by the State Plant Board of Mississippi and the Bureau of Entomology and Plant Quarantine in phony peach eradication, is now overseas and is a sergeant in the Transportation Corps.

FIRST LIEUTENANT R. Z. PEPPER

R. Z. Pepper, '27, employed for the past several years as inspector of the State Plant Board at Laurel, Mississippi, was recently commissioned a first lieutenant in the Sanitary Division of the Medical Corps and is now stationed at Camp Joseph T. Robinson, Arkansas.

PRIVATE J. B. SMITH

J. B. Smith, '38, for several years employed on white-fringed beetle eradication, B.E.P.Q., was inducted into the Army in March, 1943 and is stationed at present at Camp Shelby, Mississippi.

R. L. DUBUISSON

R. L. Dubuisson, '42, employed on white-fringed beetle eradication for the Bureau of Entomology and Plant Quarantine at Gulfport, Mississippi during the summer of 1941, is in the Navy and was last heard from at Bainbridge, Md.

PRIVATE A. W. FAULK

A. W. Faulk, '42, employed by the State Plant Board of Mississippi for one or two summers as an assistant in apiary inspection, is now located with the Medical Detachment of the Army Air Force Technical Training School, Gulfport Field, Mississippi.

SECOND LIEUTENANT J. T. ROY

J. T. Roy, x'33, formerly engaged in white-fringed bettle eradication for the Bureau of Entomology and Plant Quarantine at Hattiesburg, Mississippi, is now a second lieutenant in the Military Police Force.

PRIVATE W. L. LOWRY

W. L. Lowry, '30, formerly employed by the State Plant Board of Mississippi in Argentine ant eradication and more recently with the Division of Cotton Insect Investigations, B.E.P.Q., is now serving overseas and when last heard from was a private.

PRIVATE PAUL K. ADAMS

Paul K. Adams, '42, previously employed by the State Plant Board of Mississippi and the Bureau of Entomology and Plant Quarantine on phony peach disease eradication, is now a private in the Medical Detachment of the U. S. Air Force at Keesler Field, Mississippi.

FIRST LIEUTENANT W. C. MCDUFFIE

W. C. McDuffie, '31, formerly located at Salt Lake City with the Alfalfa Weevil Project, B.E.P.Q., and more recently in Florida. has received a commission as first lieutenant in the Sanitary Corps. He was stationed first at Lawson General Hospital, Atlanta and is now located in Orlando, Florida.

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Roger Anderson

Roger Anderson (M.S. in Entomology, University of Minnesota, 1941) is doing termite control work for the War Department. His headquarters are 223 Federal Building, Asheville, N. C.

Sergeant Herbert C. Barnett

Herbert C. Barnett (Graduate Assistant in Entomology, University of Minnesota) has been stationed at the Army Medical School in Washington, D. C. for approximately a year and a half. He is assisting with the teaching of parasitology and tropical medicine. His address is Division of Parasitology and Tropical Medicine, Army Medical School.

Pharmacist's Mate 2/c Daniel M. Benjamin

Daniel M. Benjamin (Graduate Assistant in Entomology, University of Minnesota) is stationed at the U. S. Naval Hospital, Newport, R. I. He is working in the eye, ear, nose and throat operating room there. His address is U. S. Naval Hospital Staff, Newport, R. I.

Second Lieutenant A. A. Bertagnolli

A. A. Bertagnolli (Graduate Student in Entomology, University of Minnesota) finished his officers candidate training and was commissioned Second Lieutenant in the fall of 1942. He was assigned to the Chemical Warfare Service at Barksdale Field, La., but has been moved from there and his address at the present time is unknown.

Staff Sergeant Everett G. Blood

Everett G. Blood (Graduate Assistant in Entomology, University of Minnesota) was serving with the Medical Detachment at Fort Benning, Ga. according to the last news from him. His address is Medical Detachment, 323 S.T.R., Fort Benning.

Second Lieutenant A. W. Buzicky

A. W. Buzicky (M.S. in Entomology, University of Minnesota, 1940) was commissioned in the Medical Corps of the Army in December, 1942. Early in 1943 he was transferred to the Sanitary Corps and moved to Camp Robinson, Arkansas. In May he was assigned to Camp Crowder, Missouri to take over the mosquito control work in that camp, formerly handled by Captain A. B. Gurney.

First Lieutenant LeRoy D. Christenson

LeRoy D. Christenson (a former Graduate Student in Entomology, University of Minnesota) was at New Orleans, La. early in 1943, taking a course of training in malaria control. He has gone overseas with a malaria control unit. His last address in this country was 3rd Malaria Survey Unit, New Orleans Staging Area, New Orleans, La.

Lieutenant Reed Christenson

Reed Christenson (Ph.D. in Parasitology, University of Minnesota, 1933) took the malaria control course at the New Orleans Staging Area early in 1943 and has now been shipped overseas. His address is unknown.

First Lieutenant Walter Connell

Walter Connell (M.S. in Entomology, University of Minnesota, 1941) has recently been assigned to the Malaria Control School, New Orleans Staging Area, New Orleans, La.

Lieutenant (j.g.) Richard H. Daggy

Richard H. Daggy (Ph.D. in Entomology, University of Minnesota, 1941) was assigned to the Marines in April 1942 and went overseas with the Marines who made the first landing on Guadalcanal. He was injured while the Guadalcanal invasion force was preparing to embark from its South Pacific base and was hospitalized for several months. He was then transferred back to the Navy and assigned to malaria control in the South Pacific for the Navy. His address is Naval Advanced Base, Navy 212, M Division, Fleet Post Office, San Francisco, California.

Donald G. Denning, *Assistant Entomologist* (R)—(USPHS)

Dr. Donald Denning (Ph.D. in Entomology, University of Minnesota, 1942) has been working on malaria control with the U. S. Public Health Service since June 1942. He was stationed for several months at Philadelphia, Pa. and in the fall of 1942 was transferred to New Orleans, La. He has recently been assigned to Columbia, S. C.

Warrant Officer Edwin Dery

Edwin Dery (Graduate Student in Medical Entomology, University of Minnesota) who entered the service of the U. S. Army in September 1941 has served at numerous posts in the eastern and western parts of the United States while training as a water supply officer. During the winter of 1942–43 he was stationed in southern California on water supplies for the army units in desert areas. He has now been transferred overseas. His address is 487th Engineering Water Supply Battalion, A.P.O. 545, c/o Postmaster, Los Angeles, California.

H. Rodney Dodge

H. Rodney Dodge (M.S. in Entomology, University of Minnesota, 1938) has been with the U. S. Public Health Service working on mosquito control since June, 1942. His address is U. S. Public Health Service, P. O. Box 1095, Macon, Ga.

Harold Elishewitz

Harold Elishewitz (Ph.D. in Medical Entomology, University of Minnesota, 1942) is serving as a civilian research worker at the Naval Medical Research Institute, Bethesda, Maryland.

Winston Elkins

Winston Elkins (M.S. in Entomology, University of Minnesota, 1935) a former student of Trichoptera at the University of Minnesota, is now with the Army Air Force. His address is 73rd Bombardment Squadron, A.P.O. 948, c/o Postmaster, Seattle, Washington.

CAPTAIN FRANK W. FISK

Frank W. Fisk (former Graduate Assistant in Entomology, University of Minnesota) who went abroad with a malaria control staff for work on the Burma road in November 1941, is now stationed in India. His address is Medical Section, S.O.S., A.P.O. 689, c/o Postmaster, New York, N. Y.

ENSIGN C. GORDON FREDINE

C. Gordon Fredine (Graduate Assistant in Parasitology, University of Minnesota) was commissioned in the Navy in April and is now at the Naval Medical Center, Bethesda, Maryland. He was formerly in charge of game management work at Purdue University. His address is H-V (S), U.S.N.R. Medical School, Naval Medical Center, Bethesda.

CAPTAIN ASHLEY B. GURNEY

Ashley B. Gurney, (former Graduate Student in Entomology, University of Minnesota) who has been stationed at Camp Crowder, Mo. was recently sent to Florida for a short course on malaria control. At the termination of that course he was assigned to the New Orleans Staging Area for training with a Malaria Survey Unit. His present address is Malaria Training Center, New Orleans, La.

PHILIP H. HARDEN, *Assistant Entomologist* (R)

Philip H. Harden (M.S. in Entomology, University of Minnesota, 1941) has been serving with the U. S. Public Health Service on malaria control since June, 1942. His address is U. S. Public Health Service, 207 Civil Courts Building, New Orleans, La.

MAJOR MARSHALL HERTIG

Marshall Hertig (Ph.D. in Medical Entomology, University of Minnesota, 1922) returned from several years work in Peru in December, 1942. He was commissioned a Major in the Army Sanitary Corps in February and taught medical entomology at the Army Medical School, Washington, D. C. until recently. He has now been assigned to work in Panama and his present address is Gorgas Memorial Laboratory, Panama, Republic of Panama.

FIRST LIEUTENANT PAUL HIGHBY

Paul Highby (Ph.D. in Parasitology, University of Minnesota, 1942), formerly with the Minnesota State Conservation Commission was commissioned in the Army in April and was stationed at the Army Medical School, Army Medical Center, Washington, D. C. His present address is A.P.O. 4166, c/o Postmaster, San Francisco, California.

PRIVATE FIRST CLASS JOHN D. HITCHCOCK

John D. Hitchcock (M.S. in Entomology, University of Minnesota, 1935) who was formerly with the Rocky Mountain Bee Laboratory at Laramie, Wyoming, is with the Army at Camp Forrest, Tennessee. His address is 4th Platoon, 300th General Hospital, Camp Forrest, Tenn.

MAJOR WILLIAM L. JELLISON

William L. Jellison (Ph.D. in Medical Entomology, University of Minnesota, 1940), who went overseas with a malaria commission for work on the Burma Road in November, 1941, is now stationed in India on malaria control. His address is A.P.O. 629, c/o Postmaster, New York, N. Y.

CORPORAL THOMAS H. JOHNSON

Thomas H. Johnson (Graduate Student in Parasitology, University of Minnesota) who entered the Army in the fall of 1942, was trained in a medical technicians school in Atlanta and sent to Fitzsimon's General Hospital in Denver. He has recently been assigned to the New Orleans Staging Area for training in malaria control.

TAMARATH KNIGIN

Miss Tamarath Knigin (Graduate Student in Medical Entomology, University of Minnesota) of the Army was sent to South America in late 1941 for work on malaria control. Her address is Malaria Laboratory, Office of Sector Surgeon, A.P.O. 868, c/o Postmaster, New York, N. Y.

HERBERT KNUTSON, *Assistant Sanitarian* (R)

Dr. Herbert Knutson (Ph.D. in Entomology, University of Minnesota, 1941) formerly on the staff of the Department of Zoology, University of Rhode Island, is now with the U. S. Public Health Service. He is stationed at Washington, D. C. working on mosquito control in the Potomac River.

CAPTAIN GLEN KOHLS

Glen Kohls (M.S. in Entomology, University of Minnesota, 1937) formerly a member of the staff of the Rocky Mountain Laboratory, Hamilton, Montana, was commissioned in the Army the first part of April and assigned to the Army Medical School, Washington, D. C. teaching Medical Entomology.

LIEUTENANT (j.g.) GERHARD KRETZSCHMAR

Gerhard Kretzschmar (Graduate Assistant in Entomology, University of Minnesota) enlisted in the Coast Guard in August, 1941, was later sent to an Officers Candidate School and was commissioned an Ensign in June, 1942. Since that time he has been assigned to the Philadelphia District Office in charge of chemical warfare and ordnance. His address is District Coast Guard Office, 310 North Washington Square, Philadelphia, Pennsylvania.

FIRST LIEUTENANT OSCAR V. LOPP

Oscar V. Lopp (M.S. in Engomology, University of Minnesota, 1931) has been commissioned in the Sanitary Corps and assigned to duty at Ft. Belvoir.

LIEUTENANT (j.g.) HORACE LUND

Horace Lund (Ph.D. in Entomology, University of Minnesota, 1936) was commissioned in the Navy in the spring of 1942 and has been stationed since that time at the Naval Air Station, Elizabeth, N. C. where he is working on mosquito control.

ENSIGN JOHN T. MEDLER

John T. Medler (Ph.D. in Entomology, University of Minnesota, 1940) a Guggenheim Fellow in 1942 and formerly with the U. S. Public Health Service on mosquito control at Porterville, California, was commissioned in the Navy early in 1943 and has since been stationed at the Mare Island Navy Yard. His address is H-V (S) U.S.N.R., Yard Dispensary, Mare Island, California.

FIRST LIEUTENANT HERBERT E. MILLIRON

Herbert E. Milliron (Ph.D. in Entomology, University of Minnesota, 1942) was commissioned in the

Army Sanitary Corps in September, 1942, and was stationed at Camp Grant, Illinois. He has since served at Camp Knox, Kentucky and is now stationed at Camp Atterbury, Indiana. His address is 1560 Service Unit, Medical Section, Station Hospital, Camp Atterbury, Indiana.

H. PAGE NICHOLSON, *Assistant Entomologist* (R)

H. Page Nicholson (M.S. in Entomology, University of Minnesota, 1941) has been with the U. S. Public Health Service since June 1, 1942. He is stationed at Norfolk, Va. on mosquito control. His address is 300 Essex Building, Norfolk, Va.

CAPTAIN WILLIAM B. OWEN

William B. Owen (Ph.D. in Entomology, University of Minnesota, 1936) was commissioned in the Army Sanitary Corps early in 1943 and assigned to Carlisle Barracks, Pennsylvania. Since finishing his work there he has been assigned to the Army Medical School at Washington, D. C.

LIEUTENANT (j.g.) CALVIN PEDERSON

Calvin Pederson (B.S. in Entomology, University of Minnesota, 1939) was commissioned in the Navy in February, 1942, and assigned to mosquito control work in Puerto Rico. After some six months service on that Island he was transferred to Trinidad, B.W.I. and is in malaria control work there. His address is Malaria Control Laboratory, U. S. Naval Air Station, Trinidad, B.W.I.

FIRST LIEUTENANT HAROLD PETERS

Harold Peters (Ph.D. in Entomology, University of Minnesota, 1942) was commissioned in the Army Sanitary Corps in September, 1942, and has since been stationed at Camp Pickett, Virginia. His address is Station Hospital, Camp Pickett, Va.

ALLAN PETERSON, *Assistant Entomologist* (R)

Allan Peterson (Graduate Assistant in Entomology, University of Minnesota) has been with the U. S. Public Health Service since June, 1942. He is stationed at Jackson, Mississippi on malaria control work. His address is State Board of Health, Jackson.

MAJOR C. B. PHILIP

C. B. Philip (Ph.D. in Medical Entomology, University of Minnesota, 1930) was commissioned in the Army in July, 1942, and assigned to the Army Medical School, Washington, D. C. where he taught medical entomology until April of this year. He is abroad with the typhus commission. His address is A.P.O. 4121, c/o Postmaster, New York.

FIRST LIEUTENANT D. J. PLETSCH

D. J. Pletsch (Ph.D. in Entomology, University of Minnesota, 1942), a member of the Entomology staff at Montana State College, Bozeman, Montana, was commissioned in the Army in April, 1943, and assigned to Camp Barkeley, Texas. His address is M.D.R.P., and M.R.T.C., Camp Barkeley.

HARRY D. PRATT, *Assistant Entomologist* (R)

Dr. Harry Pratt (Ph.D. in Entomology, University of Minnesota, 1941) has been with the U. S. Public Health Service since June, 1942. He was assigned to malaria control work in Puerto Rico and has been stationed there since the summer of 1942. His address is Assistant Entomologist (R), U.S.P.H.S., District 6, San Juan, Puerto Rico.

A. EARL PRITCHARD, *Assistant Entomologist* (R)

Dr. A. Earl Pritchard (Ph.D. in Entomology, University of Minnesota, 1942) is carrying on malaria control work for the U. S. Public Health Service in Puerto Rico. His address is A.P.O., 848, c/o Postmaster, New York, N. Y.

LIEUTENANT DON C. QUIMBY

Don C. Quimby (Instructor in Game Management at the University of Minnesota) completed his course in officers candidate school last February and is now stationed at San Mateo, California with an anti-aircraft division. His address is Battery K, 216th C.A. (AA), San Mateo, California.

CORPORAL MORRIS ROCKSTEIN

Morris Rockstein (Graduate Assistant in Entomology, University of Minnesota) has served at Sheppard Field, Texas, Chanute Field, Illinois, Bradley Field, Connecticut, Washington, D. C. and Grand Rapids, Michigan while training as a weather observer. He is now taking advanced training at Grand Rapids, Michigan. His address is 35th T.S.S., A.A.F., Pantlind Exhibition Bldg., 5th Floor.

SECOND LIEUTENANT HUGO G. RODECK

Hugo G. Rodeck (Graduate Student in Entomology, University of Minnesota) director of the Natural History Museum at the University of Colorado, Boulder, Colo. was commissioned in the Army in April and is now training at Miami Beach, Florida. His address is A.A.F., O.T.S., Miami Beach.

CAPTAIN PHILIP M. SCHROEDER

Philip M. Schroeder (M.S. in Entomology, University of Minnesota, 1941) has been with the Army since the fall of 1941. He is stationed at the University of Minnesota in the R.O.T.C. unit.

SERGEANT IRVIN B. TARSHIS

Irvin B. Tarshis (Graduate Student in Entomology, University of Minnesota) has been in the Army since September, 1942. He was stationed for six weeks at Camp Barkeley, Texas and then sent to a medical technicians school at Fitzsimmon's General Hospital, Denver, Colorado. His present address is 143rd Station Hospital, Camp Bowie, Texas.

FIRST LIEUTENANT E. R. TINKHAM

E. R. Tinkham (Ph.D. in Entomology, University of Minnesota, 1939) entered the Army in August, 1942, and was sent to Camp Barkeley, Texas, then to Fort Lewis, Wash. and in January was commissioned in the Sanitary Corps and transferred to Camp Dix, N. J. He is now at Boca Raton Field, Florida in mosquito control work.

CAPTAIN F. G. WALLACE

F. G. Wallace (Ph.D. in Parasitology, University of Minnesota, 1933) was commissioned in the Medical Corps of the U. S. Army in August, 1942, and has been stationed for some months at Fort Sam Houston, Texas. The First Medical General Laboratory, to which he is assigned, has recently been moved to New York and probably overseas. His latest address is First Medical General Laboratory, A.P.O. 3385, c/o Postmaster, New York City, N. Y.

LESTER TJERNLUND

Lester Tjernlund (B.S. in Entomology, University of Minnesota 1939) enlisted with the Marines early in 1942 and was reported killed in action, presumably in the South Pacific, early this year.

Notes of Purdue Men in the Service

Delmon W. LaHue, a graduate of Purdue University, for several years connected with the U. S. Cereal and Forage Insect Laboratory at Lafayette, Indiana, has received a commission as First Lieutenant in the Sanitary Corps of the Army and is stationed at Camp Grant, Illinois. (Co. A, 29th Med. Tr. Bn.)

W. D. Miller, a Purdue graduate, may be addressed Company C, Med. Det., 352, Morrison Field, West Palm Beach, Florida. He has recently taken a refresher course in mosquito identification at Fort McPherson, Georgia, and is now classified as an entomologist. Miller was formerly stationed at Kearns, Utah.

Philip Luginbill, Jr., is an Ensign in the navy and has recently visited his home in West Lafayette, Indiana. Luginbill is a Purdue graduate. He expects to be assigned to sea duty on the West Coast in the near future.

Curtis Benton, recently stationed at Fort Knox, has been returned to civilian life and has resumed his studies of hessian fly at the Bureau Laboratory at Lafayette, Indiana. Benton is another Purdue graduate.

Virgil R. Knapp, Purdue '41, writes Professor Davis from an unnamed station. He states that he has a katydid 5 inches long having antennae 6 inches in length. Perhaps this will identify his location for some of our readers.

John J. Favinger, Purdue '40, has been discharged from the Army for physical disability and has returned to his former duties in the office of the Indiana State Entomologist.

First Lieutenant C. O. Partlow (Purdue '35), a member of the Association, has been transferred from Lubbock Army Flying School and may now be addressed at Camp Hood, Texas, Co. A, Student Residence, T. D. S.

First Lieutenant Robert R. Heaton (Purdue '33) visited Lafayette recently on his way to his new station at Fort Sam Houston, Texas, where he may be addressed in care of the 15th General Laboratory. Mr. Heaton is a member of the Association and was formerly located at Indianapolis.

Harry E. Brown, a Purdue graduate recently employed at the University of Missouri and a member of the Association, received a commission as First Lieutenant in the Army and may now be addressed at Camp Barkeley, Texas, Sanitary Corps, M. D. R. P., Training Center.

PROFESSOR DEAN RETIRES RECEIVES HONORARY DEGREE

Professor George A. Dean, who has been a member of the staff of the Department of Entomology of the Kansas State College at Manhattan, Kansas, since 1902 and Head of the Department, State Entomologist and Entomologist of the Experiment Station, since the department was separately organized in 1913, retired from his administrative duties on July 1, 1943. The honorary degree, Doctor of Science, was conferred upon him by Southwestern College, Winfield, Kansas, at their spring commencement, June 1943. He will continue his regular Experiment Station, teaching, and correspondence duties for the time being as a full time Professor of Entomology and expects to revise some of his early publications now out of print.

Doctor Roger C. Smith, Professor of Entomology in the department has taken over Doctor Dean's administrative duties. Doctor Smith went to Kansas State College from the field laboratory of the Bureau of Entomology at Charlottesville, Virginia, February 1, 1920 and has been there continuously, except for a leave of absence of approximately two years for work with the Service Technique, Port-au-Prince, Haiti and a sabbatical year of travel in eastern U. S. Canada, and Europe.

PROFESSOR RUGGLES RETIRES

Professor A. G. Ruggles has retired, as of July 1, 1943, from his active work at the University of Minnesota. His duties have been extensive and included teaching, as Professor of Entomology in the University, research, as Experiment Station Entomologist, and administrative, as State Entomologist.

Professor Ruggles has been attached to the University for more than forty years and has always been active in the affairs of the American Association of Economic Entomologists. It is stated that he will continue to serve in an advisory capacity in the office of the State Entomologist. All entomologists will confidently expect him to become even more active in the affairs of the Association as a result of his greater freedom of action.

We congratulate Professor Ruggles on his long period of active service which has earned him a degree of leisure while he still has the capacity to enjoy the freedom of action which he will now have.

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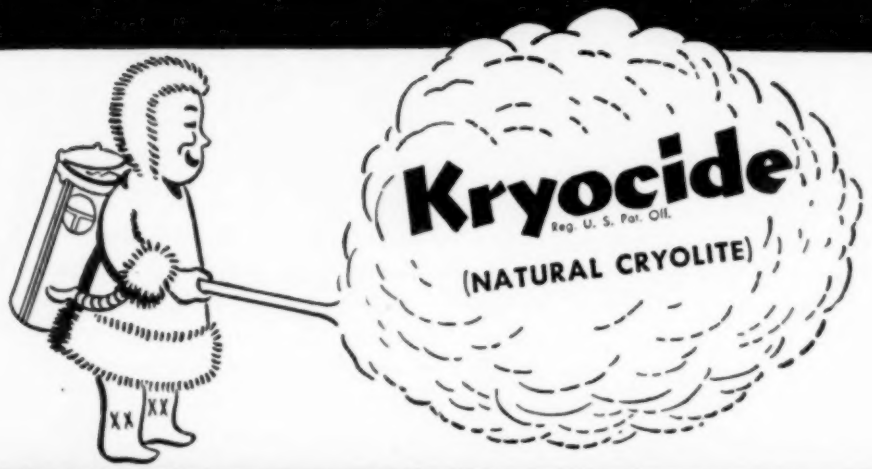

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